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WIRELESS TELEPHONY.*

BY

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FUNDAMENTAL REQUIREMENTS.

THE development of wireless telephony dates back almost as far as the original conception of the use of electromagnetic waves for wireless telegraphy. The practical utilization of this method of communication is, however, a matter of comparatively recent date as contrasted with the much longer period during which wireless telegraphy has been a practical accomplishment. This delay in the successful utilization of wireless telephony is due to certain differences in the fundamental requirements as compared with those for the telegraph. These differences and the manner in which the particular difficulties incident to the successful accomplishment of wireless telephony have been overcome will be explained in detail in succeeding paragraphs.

Broadly speaking, the principal difference between wireless telephony and wireless telegraphy lies in the form of the signal which has to be transmitted, telegraph signals being obviously far simpler in the wave-form of the signal current than are telephone signals. The fundamental requirement is, in either case,

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that the form of the receiving signal shall faithfully reproduce the form of the transmitted signal, whether due to the opening and closing of a telegraph key or the vibrations of a telephone transmitter diaphragm.

The essential units required in a complete wireless telephone system may be grouped into the transmitting and the receiving elements. The receiving elements, being in no respect different from those required in wireless telegraphy, will not be described at this point. The transmitting elements differ, however, in many respects and comprise the following essential units:

A radio frequency generator.

A modulator for controlling the radio frequency current.

An antenna for radiating the electromagnetic waves produced by the radio frequency current.

The particular characteristics of these various units are described in detail hereinafter.

Wireless telephony is subject to certain particular limitations in the same way as wireless telegraphy, notably that of interference due to atmospheric electricity or radio signals foreign to the desired signal.

HISTORICAL SUMMARY.

The first requirement for any wireless telephone station is a source of radio frequency current whose amplitude from cycle to cycle remains constant, except when varied by the modulation imposed upon it by the voice current. If variations in its amplitude occur, due to other causes, these variations will introduce disturbances which will cause the system to be deficient in the effective transmission of speech. It is at once evident that the original source of radio frequency current used in wireless telegraphy, namely, the oscillatory discharge of a condenser supplied with energy from a low frequency source, is entirely unsuited to the purposes of wireless telephony.

With the development of the Poulsen arc the first successful attempts at radio telephony were begun. These attempts involved the second factor in a wireless telephone station, namely, that of modulating the radio frequency current in accordance with the currents supplied by a telephone transmitter. The early attempts to accomplish this modulation, by means of microphones inserted

directly in the antenna circuit or coupled to the circuit in various manners, were largely unsuccessful due to the limitations of the microphone devices, such as the low current capacity and the small range of variation of resistance.

A second source of radio frequency current is the high frequency alternator, which has been developed in various forms and which has been likewise used with limited success for wireless telephone transmission. The same lack of a suitable modulating device handicapped the use of the high frequency alternator until the advent of the audion or vacuum tube. The characteristics of the vacuum tube have been fully described in many recent publications, and will be discussed in this paper only in so far as these characteristics are directly applicable to the problems of wireless telephony. It will be seen from this subsequent discussion that the vacuum tube possesses in a remarkable manner the precise characteristics required for the generation and modulation of radio frequency current for low power wireless telephone stations, and for the detection and amplification of radio signals of any character whatsoever. Its influence on the art of wireless telephony may well be compared with the influence of the gas engine on aviation.

VACUUM TUBE.

The requirements of a radio frequency generator may be grouped as follows:

The desired frequency may range roughly between the values of 15,000 and 6,000,000 cycles per second.

The frequency for any particular generator may be required to vary over a considerable range, in some cases as much as several octaves. In other cases, a single value of frequency is sufficient.

The frequency when set at a particular value should remain substantially unaffected by ordinary changes in the physical or electrical conditions associated with the station.

The current delivered by the generator should approximate a sine wave as closely as possible.

The required output for different classes of stations may vary from less than one watt to several hundred kilowatts.

The efficiency of the generator should be reasonably high though not necessarily comparable with the efficiencies obtained from ordinary types of generators.

When used as an oscillator or radio frequency generator associated with properly designed circuits, the vacuum tube will meet all of these requirements, with the exception that the power output of vacuum tubes as at present constructed is limited to not more than a few hundred watts per tube.

The requirements of a modulator for radio telephony may be grouped as follows:

The modulator should be actuated by the current from an ordinary microphone telephone transmitter or its equivalent.

The modulator should faithfully reproduce, in its effect upon the radio frequency current, the wave-form of the telephone or speech current.

The modulator should be capable of almost completely modulating the output of radio frequency generators whose power outputs may cover the range indicated above.

These requirements are fulfilled to a remarkable extent by the vacuum tube used in properly designed circuits.

Although the vacuum tube was invented in 1906, its development into a sufficiently practical form to be useful for wireless telephony was comparatively slow. This development was greatly accelerated, beginning in 1912, when the American Telephone and Telegraph Company became interested in the vacuum tube for use in telephone repeaters. Rapid improvements were made in the design and construction of vacuum tubes, and at the same time experiments were conducted looking to the use of the vacuum tube in wireless telephone apparatus. As a result of these experiments, the transmission of speech from Washington, D. C., to Paris and to Honolulu by wireless telephone occurred during the year 1915. In these experiments the vacuum tube was used as a radio frequency generator, a modulator, a detector and amplifier.

The possibilities of the vacuum tube for wireless telephony having been partly disclosed by the above experiments, the Navy Department became actively interested in the development of wireless telephone apparatus for use on battleships. Experimental sets were developed by the Western Electric Company and

extremely promising results were secured. The Signal Corps was likewise interested in the development of apparatus for the Army, but experiments had not proceeded to the point where any satisfactory apparatus had been developed prior to the declaration of war by this country.

FIELD OF MILITARY APPLICATION.

Prior to the beginning of the European War the use of wireless telegraphy in military operations had been limited to an extremely narrow field, while wireless telephony had been used to an entirely negligible extent. The communication requirements for the armies engaged in the trench-warfare style of conflict emphasized the need of radio communication, and accordingly the extent and variety of the apparatus for wireless telegraphy increased rapidly. At the time this country entered the war wireless telegraphy comprised an extremely important and extensive part of the communication systems employed on the western front. The development of wireless telephony, however, had not proceeded to the point where satisfactory apparatus was available for use by the military forces. The particular field which most urgently required its use was the airplane communication system. The limitations imposed on the use of wireless telephony, such as greater weight and complication of the apparatus, and complete lack of secrecy, had hitherto prevented favorable consideration of wireless telephony as a substitute for wireless telegraphy. The particular requirements of the airplane communication, however, introduced certain advantages which more than compensated for these factors and made telephony much more desirable than telegraphy. The controlling reason for the use of the wireless telephone lay in the fact that its use eliminated the necessity of a knowledge of the telegraph code on the part of the aviator. An additional advantage lay in the greater speed with which the telephone transmission can be effected.

Inasmuch as the airplane wireless telephone set comprises not only the most interesting example of the use of wireless communication during the war, but furnishes also a remarkable example of the rapidity with which the engineering and manufacturing facilities of this country were adapted to war-time needs, a detailed summary of the development, production and operation of

this set forms an important part of the general subject of wireless telephony.

HISTORICAL REVIEW.

Almost immediately following the declaration of war by this country, the Chief Signal Officer of the Army issued orders for the development of an airplane wireless telephone set which was to furnish telephone communication between the different airplanes of a squadron and also to furnish communication between an airplane and a ground station. The fundamental requirements for this set were based partly on information furnished by the Allies, and partly on the experience of the U. S. Signal Corps in the pre-war experiments in airplane radio telegraphy and telephony. The actual development work was entrusted to the Engineering Department of the Western Electric Company, with provision for the necessary airplane facilities and information to be supplied by the Signal Corps as required. The progress of the development work was extremely rapid, successful communication being established between an airplane and a ground station within six weeks from the date the development was started. The evolution of a complete design suited to commercial production likewise proceeded very rapidly, so that by December, 1917, only six months from the time the development work was started, the design of the complete equipment had reached the stage where production of the sets in quantity could be authorized. As early as October, 1917, the apparatus had been developed to a sufficiently complete extent to warrant sending samples to the Expeditionary Forces for test under conditions existing at the front.

Because of the extreme need for the earliest possible delivery of apparatus in large quantities, to meet the needs of the airplane program of the United States, the production of airplane telephone sets was begun prior to the completion of the experimental work. As further experiments indicated the need of modification or refinements in the design, the necessary changes were incorporated in the process of manufacture, so that the sets delivered in the spring of 1918 embodied the results of experimental work extending almost up to the date of completion of the sets.

Beginning early in the summer of 1918 the development of an improved type of set was begun, and at the time of the armistice this development had reached the point where practical trials of

the completed sets were in progress. The essential differences between the original type of set and this new set are described in some detail in succeeding paragraphs.

The production of several thousand of the airplane wireless telephone sets in the brief space of a few months involved many problems of an extremely unusual and difficult nature. As an example may be cited the production of the vacuum tubes required for use in the sets. Prior to the war the vacuum tubes had never been produced at rates greater than a few hundred tubes per week. At the time of the armistice the production of these tubes in one factory alone was in excess of 25,000 per week, the largest part of which was intended for use with the airplane wireless telephone sets. The problem of devising methods for testing the completed sets involved the development of unusual testing facilities and the creation of a large organization of inspectors to handle the sets as rapidly as they were delivered from the factory. It was obviously impossible to test each completed set in an airplane before considering it as finally accepted, so that the formulation of the testing specifications involved the development of tests which would approximate the conditions encountered on airplanes and at the same time would be adapted to factory methods of testing.

Before the development of the airplane wireless telephone sets had proceeded even to the point where success was assured, it became apparent to those involved in the work that the production of a satisfactory set was by no means the complete solution of the problem. The successful use of the equipment would undoubtedly require a considerable amount of training of the aviators and a very considerable period of experiment with the trained aviators using the equipment before its limitations and its possibilities could be even approximately determined. Accordingly preparations were made in advance of the delivery of the first production sets, to institute a course of training which was intended both to familiarize the aviator with the actual use of the set and to work out the method of use; in other words, the tactics of a voice-commanded airplane squadron. As early as May, 1918, groups of airplanes using the wireless telephone sets were being trained in the use of this equipment and were being drilled in the evolutions which the equipment made possible. In June, 1918, a squadron of 39 airplanes, equipped with wireless telephone

sets, went through a course of drill in the air in such a manner as to demonstrate the remarkable possibilities of a voice-commanded squadron. Subsequently the training of aviators in the tactics of "V. C." flying progressed at a rapidly increasing rate, so that at the time of the signing of the armistice many thousand flights had been made. The record of these flights is a glowing tribute to the efficiency of the design of the airplane wireless telephone sets, which performed in such a manner as to give far less trouble than the airplane engine.

AIRPLANE SETS.

At the outset of the war-time development work on the airplane wireless telephone apparatus the requirements which the apparatus would have to meet and the particular conditions under which it would operate were largely unknown; this information became apparent more or less gradually during the progress of the development work, which fortunately proceeded along such lines as to substantially comply with the requirements as they developed. As originally conceived, these requirements may be briefly stated as follows:

> The apparatus should be capable of effecting reliable telephone communication between two airplanes at distances up to 2000 yards.
>
> The weight of the apparatus should be the minimum possible consistent with meeting the range requirements and other conditions imposed on the operation.
>
> The apparatus should be of the simplest possible construction and should require the minimum amount of adjustment or manipulation by the aviator.

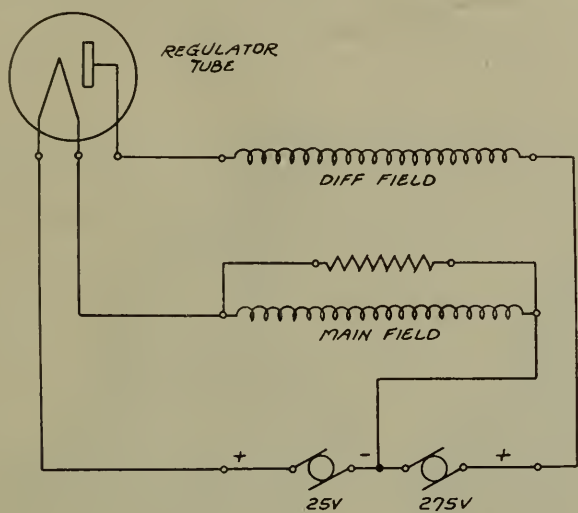
It was realized that special conditions would be encountered on the airplane which would make the development work extremely difficult and would require radical departures from any previous practice. Among these special conditions may be mentioned the tremendous noise and vibration created by the engine and wind, the necessity of reducing the fire hazard to a minimum, and, above all, the extremely essential condition that the wireless telephone apparatus must create the minimum possible interference with the various other functions of the aviator.

The various elements comprising the complete wireless telephone set may be grouped into the following units:

Power Plant.
Transmitting Unit.
Receiving Unit.
Antenna System.

The details of these various units and the problems encountered in their development are briefly described in the following paragraphs:

FIG. 1.



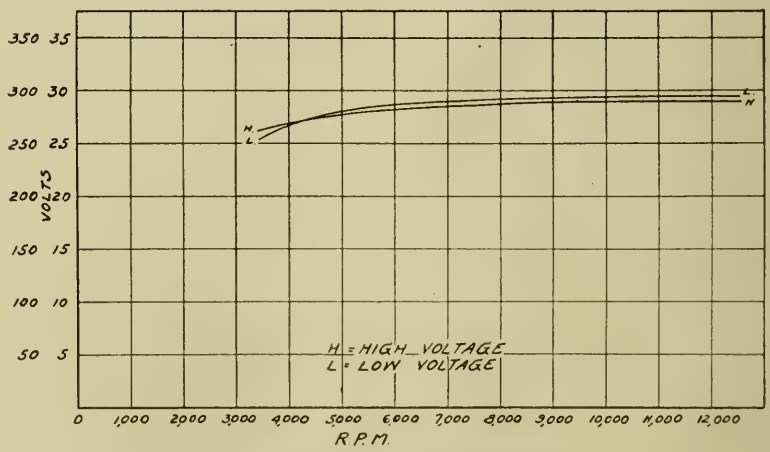
Circuit diagram, wind-driven generator.

POWER PLANT.

The preliminary experiments with various types of apparatus soon determined the power requirements of the apparatus which included power supply for the filament and plate circuits of the vacuum tubes for both transmitting and receiving circuits and power for the telephone transmitters. The filament power required was determined to be 1.35 amperes at 24 volts and the plate circuit power for the transmitting set .070 amperes at 275 volts. The plate current for the receiving tubes was extremely small, namely, less than .004 amperes, and it was decided to furnish this power from dry batteries. After various arrangements were tried the current for the telephone transmitter was obtained by shunting this transmitter about filaments of two vacuum tubes

which gave approximately the correct voltage for operating this transmitter. The 24-volt and 275-volt power is obtained from a double voltage direct current generator which is driven by an air fan, the complete generator being mounted on one of the struts of the landing gear of the airplane and hence being directly in the propeller blast. The most difficult problems involved in the design of the generator were those related to the excessive speed variation and the extremely high maximum speed at which the generator was required to operate. The air speed of the plane being subject to extremely wide variations and the air fan rotational speed varying in almost exactly the same ratio, it was necessary for the

FIG. 1a.



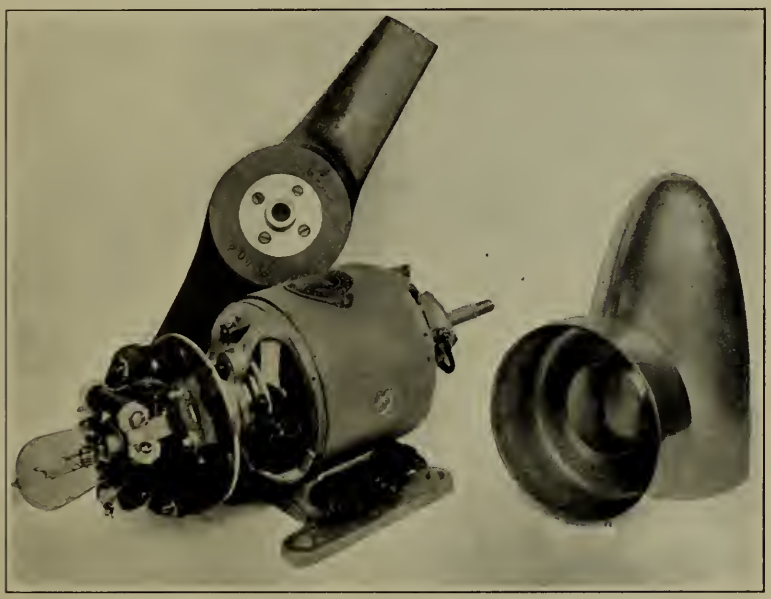
Voltage characteristic, wind-driven generator.

generator to furnish its normal voltages over a speed range of 4000 to 12,000 r. p. m. This required the use of a special voltage regulator, the circuits of which are shown in Fig. 1. This regulator depends for its operation upon the relation existing between the filament current and the electron emission from the filament in a special vacuum tube which has been designated as a regulator tube. At the lower limit of the operating speed range, namely, 4000 r. p. m., the filament of this regulator tube operates at a temperature which gives practically no emission of electrons. As the speed of the generator increases above this value the voltage rises, and accordingly the temperature of the regulator tube filament increases. This results in an extremely rapid increase in the

number of electrons emitted by the regulator tube filament, which in turn causes a rapid increase in the current flowing through the differential field and the plate circuit of the regulator tube, as shown by the characteristic curves of Fig. 2. This current tends to reduce the total magnetization of the generator, and, as a result, the voltage regulation is maintained within extremely close limits.

While this voltage regulating device operates in an extremely satisfactory manner, the excessive speed variation of the generator imposes certain other requirements on the generator design

FIG. 1b.



Wind-driven generator, fan and regulator tube.

which make it desirable to reduce this speed variation. The development of a constant speed air fan has progressed practically to the point where designs are available for an air fan which will give an almost exactly constant rotational speed with a range of air speeds of at least 4 to 1. The use of such an air fan on future wind-driven generators for airplanes is a practical certainty.

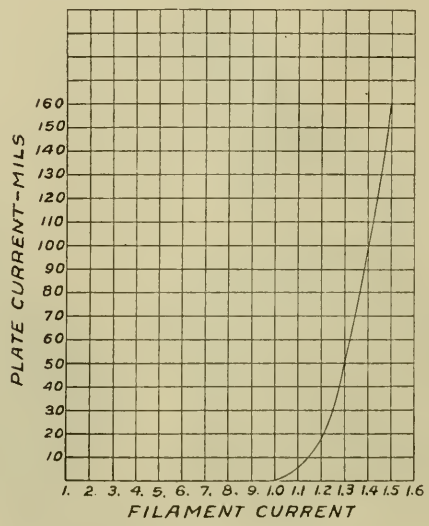
Various alternatives, such as storage batteries and a dynamotor, or a double voltage generator driven directly from the

airplane engine, were considered and rejected in favor of the generator above described.

TRANSMITTING SET.

The circuits of the transmitting set are shown schematically in Fig. 3. A single vacuum tube of a special type is used for furnishing the radio frequency current and a similar tube is used for modulating the radio frequency current. The method of modulation employed is known as the " constant current " method and may be described briefly as follows:

FIG. 2.



Characteristic curve, regulator tube.

The plate circuits of the vacuum tube oscillator and modulator are connected in parallel and are supplied through an inductance coil, which tends to maintain the total current constant. The plate current taken by the modulator tube is controlled by its grid voltage, which in turn is determined by the operation of the telephone transmitter. These voice frequency fluctuations of the modulator plate current cause corresponding variations in the direct current supplied to the plate circuit of the oscillator tube, the sum of the two currents at any par-

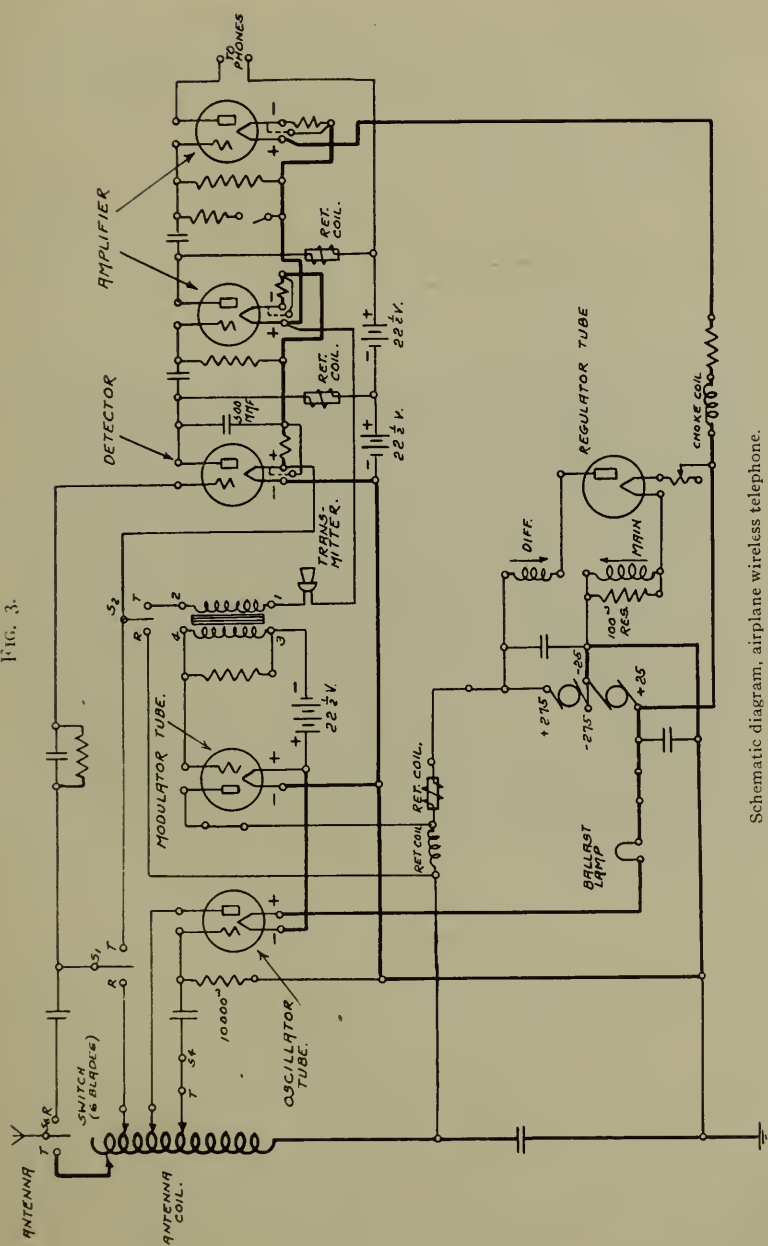


FIG. 3.

Schematic diagram, airplane wireless telephone.

ticular instance being substantially constant. These variations in the direct current supply of the oscillator tube result in corresponding variations of its high frequency output so that the result is a modulated radio frequency current supplied to the antenna.

The telephone transmitter furnished one of the most difficult problems in connection with the design of the transmitting set by reason of the fact that this transmitter operates under conditions of such extreme noise due to the wind and engine exhaust. After a very extended period of development the present form of transmitter was perfected, its improvement over the ordinary form being roughly indicated by the statement that the ratio of noise signals to speech signals in the output of this transmitter is probably less than 1 per cent. of the same ratio for a transmitter of the usual type.

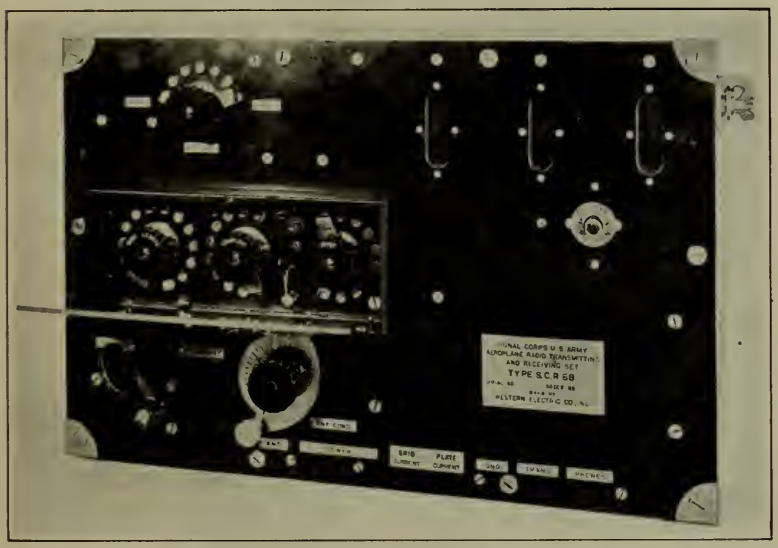
Reference to the schematic diagram indicates the adjustments of the transmitting set for different wave-lengths to include only a variable inductance and a variable capacity. Inasmuch as the apparatus is adjusted for a particular wave-length before the airplane leaves the ground, an artificial antenna whose constants approximate those of the normal antenna is used for making such adjustments on the ground.

RECEIVING SET.

The circuits of the receiving set are likewise shown schematically in Fig. 3. Reference to this figure will indicate that the circuit comprises a single resonant circuit, a vacuum tube detector, two vacuum tubes used as amplifiers, and a special helmet containing the receivers. The dectector and amplifier are not particularly novel in any respect, but the helmet containing the receivers is of very unusual construction. The same noise conditions which were mentioned above for the telephone transmitter likewise affected the reception of signals in the telephone receivers. It was accordingly necessary to develop a special sound-insulating helmet in which the telephone receivers were mounted in such a way as to exclude almost completely from the aviator's ears all sounds except those emanating from the telephone receivers. The design of a helmet which would accomplish this and at the same time not prove to be uncomfortable represents one of the most striking accomplishments in the complete set.

The adjustment of the receiving set is of the utmost simplicity, there being only a variable capacity and inductance to adjust for the particular wave-length of the received signal. As in the case of the transmitting set, these adjustments are ordinarily made before the plane leaves the ground, and it is usually necessary for the aviator to make in flight only an extremely small adjustment in the capacity to insure the proper tuning of the receiving set. Because of the condition of vibration existing on the airplane and the effect of this vibration on the vacuum tubes used in the

FIG. 4.



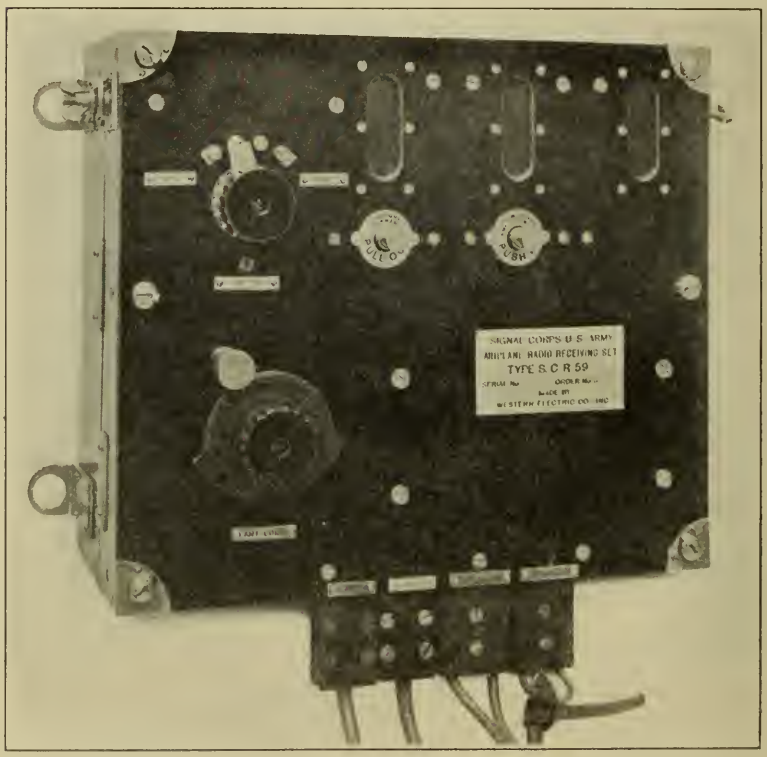
Transmitting and receiving unit.

receiving apparatus, it was necessary to devise a mechanical filter which would protect the vacuum tubes from these vibrations. The method finally adopted consisted of the use of sponge rubber supports for certain elements within the set box itself.

The current required by the plate circuits of the receiving tubes and the negative grid potential for the modulator tube of the transmitting set are furnished by small dry batteries, which consist of 15 cells of very special construction weighing less than one pound and having sufficient current capacity to operate the set a few hours a day for a considerable number of weeks. The most

important requirement for these batteries, however, was a sufficient length of shelf-life, inasmuch as a period of several months usually elapsed between the date of manufacture and the date of use. Difficulties of securing even a few months' shelf-life for cells of such small size made the use of standard cells out of the

FIG. 5.



Receiving unit.

question. Development of particular types of containers for the cells and extremely careful selection of materials resulted in the satisfactory solution of this problem.

ANTENNA.

The form of antenna which was adopted for the early experiments with the airplane wireless telephone consisted of a wire

trailing behind the airplane in flight and connected through the apparatus with the frame of the airplane as a counterpoise. The length of this wire was ordinarily 300 feet. A reel was provided for holding this wire and a small weight was attached to the free end to cause it to unreel properly after the airplane left the ground. In order to reduce the attention required by the aviator

FIG. 6.

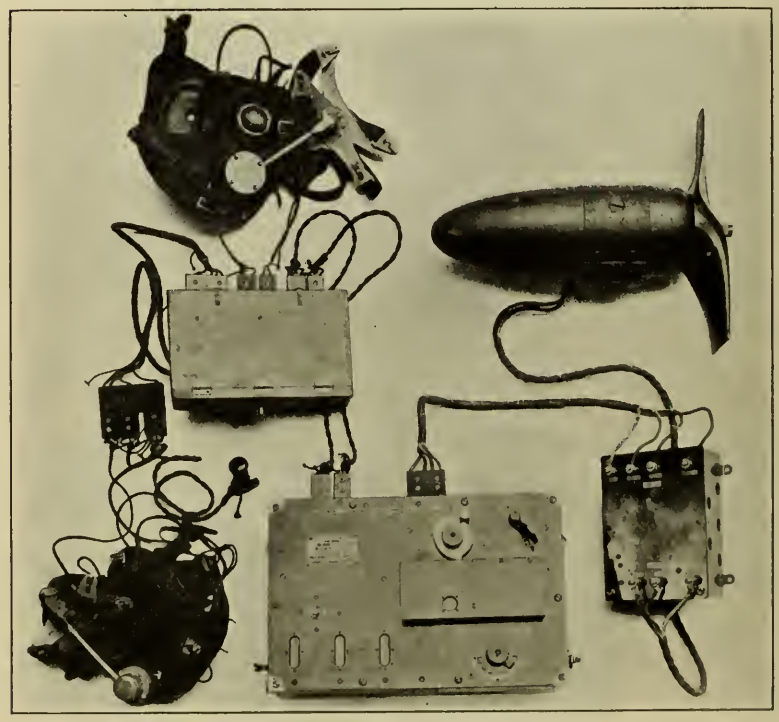
Receiving unit (open).

in unreeling the antenna a special form of reel was devised with a centrifugal governor, which limited the unreeling speed to a value which prevented the weight from breaking the wire at the end of the unreeling process. The wire which was used was a soft braided copper wire made purposely of low tensile strength, so that in case this wire became entangled with any obstruction

during flight no particular strain would be put upon the airplane structure before the antenna wire would break.

The subject of radiation from airplane antennæ has perhaps received less attention in proportion to its importance than almost any other phase of airplane wireless telephony. This is partly due to the fact that the form of antenna above described possesses

FIG. 7.



Complete transmitting and receiving set.

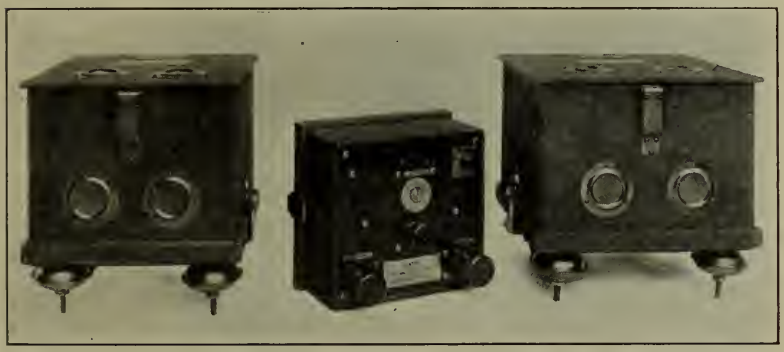
extremely efficient radiating properties and partly to the fact that investigations of the subject require very extensive and painstaking measurements involving actual flights of airplanes. The investigations conducted during the war, however, included a large number of tests of various types of antenna, the principal object of which was to evolve a substitute for the long trailing wire which would be better adapted for use on airplanes engaged

in acrobatic flying. Obviously the movements of an airplane were somewhat restricted by the use of this type of antenna.

Without indicating in detail any of the alternative types of antenna which were developed and used it may be stated there are a number of forms of airplane antenna which offer considerable promise of complying with the radiation requirement and at the same time offer practically no interference with the movements of the airplane.

The tactical uses of the airplane wireless telephone called for transmission and reception on certain airplanes and for reception only on other airplanes. The apparatus developed therefore included two distinct types, one including both the transmitting

FIG. 8.



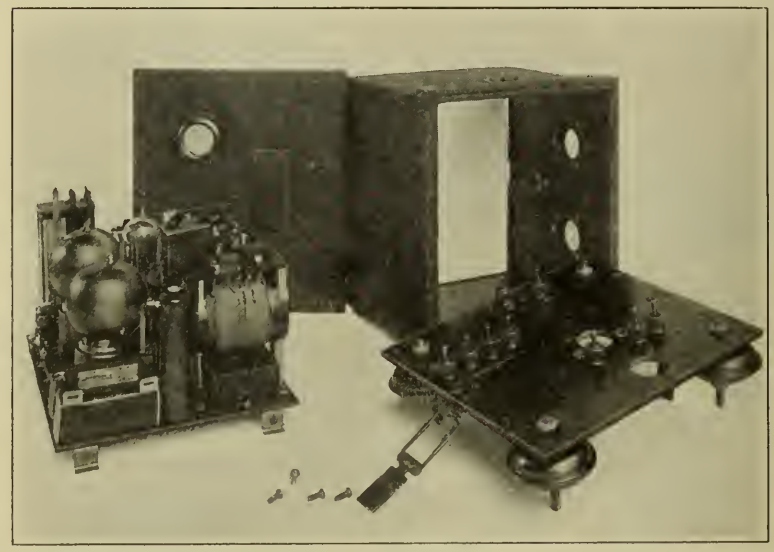
New type of airplane wireless telephone.

and receiving elements mounted in a single box, as shown in Fig. 4, while the other included only the receiving element as shown in Figs. 5 and 6. The complete equipment comprising the transmitting and receiving set is shown in Fig. 7. The complete equipment comprising the receiving set only is different with respect to the power plant, which in this case consists of a 4-volt storage battery. This figure shows two telephone transmitters and two helmets, which are used in connection with an interphone system provided as an auxiliary to the wireless telephone. This interphone system enables two persons in the same airplane to converse with each other by ordinary telephone, and furnishes in itself a valuable communication system entirely exterior to the wireless telephone apparatus.

Where communication between an airplane and a ground station is desired this communication is effected by means of a special ground set which has been developed to correspond with the range and wave-length requirements of the airplane apparatus.

In using the apparatus above described, the only manipulation required of the aviator is switching from the transmitting to the receiving apparatus, or *vice versa,* as required. Ranges of several miles between planes are easily accomplished, and under

FIG. 9.



Transmitting unit alone.

extremely favorable conditions much greater distances have been covered.

NEW TYPE OF APPARATUS.

Experience in the operation of the above type of wireless telephone apparatus indicated the desirability of certain improvements, particularly along the following lines:

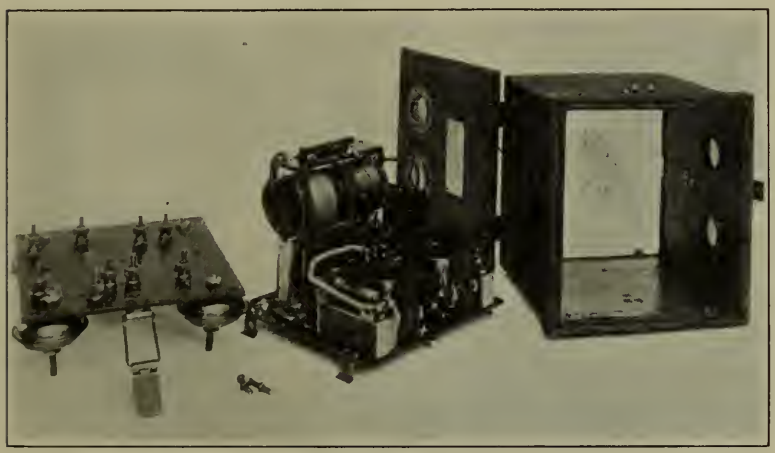
Reduction in the size of the apparatus units to better adapt them to installation in the restricted space available on certain types of airplanes.

Use of very much shorter wave-lengths to make

possible the substitution of antennæ which would not interfere with the use of the airplane and which would likewise reduce the amount of radio interference which would be experienced on the Western Front.

Accordingly, a new type of set was developed during the summer of 1918, the essential elements of which are illustrated in Figs. 8, 9, 10 and 11. Practical trials of this equipment have not proceeded sufficiently to indicate the superiority of this set from the standpoint of its use by the aviator. Its superiority, however, from the standpoint of installation is self-evident.

FIG. 10.



Receiving unit alone.

WIRELESS VS. WIRE TELEPHONY.

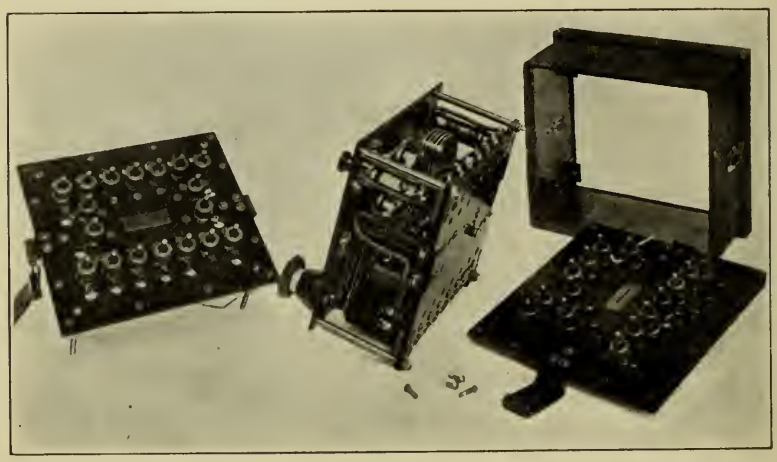
Any prophecy as to the future of the wireless telephone art should take due account of fundamental differences between wire and wireless telephony. While it is conceivable—though not probable—that improvements in directive radiation may be evolved which will cause the greater part of the waves radiated from a wireless station to choose a particular path, rather than to be spread broadcast as at present, there will always be a far more definite and restricted path for wire telephone signals than for wireless signals. As a result, it may be safely predicted that wireless telephony is not apt to supersede wire telephony in any of the fields now occupied by the latter. The application of wireless

telephony to new fields, where wire telephony is either impossible or impractical from economic considerations, will furnish abundant opportunity for service of the greatest value. A combination of wire and wireless telephony, each in its own field, may result ultimately in a telephone system covering the civilized world.

COMMERCIAL FIELD.

To the average person the most interesting commercial application of wireless telephony is transoceanic, such as is suggested by the long-distance experiments mentioned above. While the

FIG. 11.



Control unit alone.

scientific aspects of the question are such that the development of suitable apparatus for effecting reliable commercial service between such points as New York and London is a comparatively simple matter, economic questions have up to the present prevented serious consideration of such a project. It is entirely conceivable that improvements in the art may soon bring the cost of such a system well within the limits imposed by economic considerations.

Wireless telephony between ships at sea or between a ship and a shore station is a logical supplement to the wireless telegraph service now furnished on practically all ocean-going steamships. In this case, as in the case of transoceanic telephony, economic

considerations are apt to retard the extension of this field until the development of apparatus less expensive than present types.

In the field of aviation, however, wireless telephony presents a number of advantages which it is believed will result in its rapid adaptation to the needs of this service. Entirely aside from the popular interest attached to telephone communication between different airplanes, or between an airplane and a ground station, the practical value, particularly of the latter, is sufficient in many cases to justify the required expenditure to provide this facility.

There are various special fields not included in the above which may call for the use of wireless telephony, such as communication between various islands of a group—for example, the Hawaiian Islands—the wireless telephone furnishing in this case trunk lines for tying together the telephone exchanges on the various islands.

MILITARY FIELD.

The use of wireless telephone apparatus in combatant military operations during the war was practically negligible. This should, however, not be interpreted as an indication that wireless telephony offers no advantages for military purposes, but rather that the training of personnel in its use had not proceeded sufficiently to warrant its use. Communications within various units of an army frequently call for extreme mobility of the apparatus. The prevailing method of establishing intermittent communication between temporary stations joined by wires laid on the ground is obviously far from ideal. If wireless telephone apparatus can be developed by means of which different centres of command can be kept in constant touch with each other while all are in motion the advantages of such communication will compel its adoption and wide use throughout the communication system of the Army.

In naval operations the use of wireless telegraphy is so widespread that it forms an indispensable link in the naval communications system. For certain kinds of service the advantages offered by telephony as compared with telegraphy make it extremely desirable that wireless telephone apparatus be developed to meet the requirements. The present state of the art indicates the certainty that this can be done.

In the field of military aviation wireless telephony finds its greatest present opportunity for immediate service. The require-

ments of interairplane communication are such that the telephone is peculiarly adapted. The use of wireless telephony within an airplane squadron at once makes possible the development of the squadron into a military unit wherein the various members are subject to the command of the leader in exactly the same way as military units on land and water. The development of airplane squadron tactics is therefore made entirely possible, whereas without the telephone it is considered that the difficulties of communication between various airplanes would have made such a development impossible. Communication between airplanes and ground stations comprises an equally important phase of the operation of military aircraft. Hitherto these communications have been chiefly those for directing artillery fire and the wireless telegraph has served this purpose reasonably well. The availability of the wireless telephone, however, will open up new possibilities in the use of airplane to ground communication, an example of which is furnished by the present operations on the Mexican border. Scouting parties, accompanied by airplanes, traverse the extremely mountainous country, with airplanes preceding the land forces and at intervals reporting their observations. If we imagine each of the scouting parties to be equipped with receiving apparatus sufficiently portable so that it does not in any way interfere with the movements of the party, it is at once evident that they could, without delay, be kept informed of the observations of the aviator, by direct telephone communication. This extension of range of vision would be of immeasurable value.

Developments which have occurred during the war period, while essentially of a military character, are immediately applicable to both military and commercial needs. These developments point the way to further progress in the art which it is believed will, within a short time, establish wireless telephony as an important element in many phases of our military and commercial activities.

HYPERSENSITIZING COMMERCIAL PANCHROMATIC PLATES.*

BY

SAMUEL M. BURKA, Ph.D.

INTRODUCTION.

ORDINARY dry plates, which owe their sensitivity to the silver halides alone, are sensitive only to the violet and blue regions of the spectrum. If, however, a suitable dyestuff be added, the emulsion becomes sensitive to other regions, the particular region depending on the dye used. Thus erythrosin sensitizes to the green and greenish yellow, pinaverdol to the green and yellow, pinacyanol to the orange and red and dicyanin to the extreme red and infra-red.

The dyestuff is applied to the halides in one of two ways. In the commercial orthochromatic (sensitive to green and yellow) and panchromatic (sensitive to all colors) plates, the dyes are incorporated in the emulsion and the mixture flowed over the glass plate. The second method consists of bathing an ordinary blue-sensitive plate in a dilute solution of the dye and allowing the plate to dry.[1]

The bathed plates are in general faster than the commercial plates[2] and, of course, have the advantage that the plates can be sensitized for any desired region. Certain dyes, moreover (dicyanin, for example), cannot be successfully incorporated in the emulsion. The bathed plates, however, if not used soon after bathing, or if kept at a high temperature, are, in the case of most dyes, more susceptible to chemical fog. Dicyanin and pinacyanol bathed plates when prepared so as to produce the greatest sensitivity are useless after three or four days.

It has long been known that, though at the expense of keeping qualities and freedom from chemical fog, the speed of bathed plates can be increased by the addition of ammonia to the dye-

* Communicated by Dr. Enoch Karrer.

[1] Eder, "Handbuch der Photographie," 1902, vol. iii, p. 169 *et. seq.* For the Bureau of Standards methods see Bulletin Bureau of Standards, 14, 371, 1917.

[2] Eder, "Handbuch der Photographie," 1902, vol. iii, p. 169. Reference to Schumann, Oct., 1885; Phot. Wochenbl., 1885, p. 395.

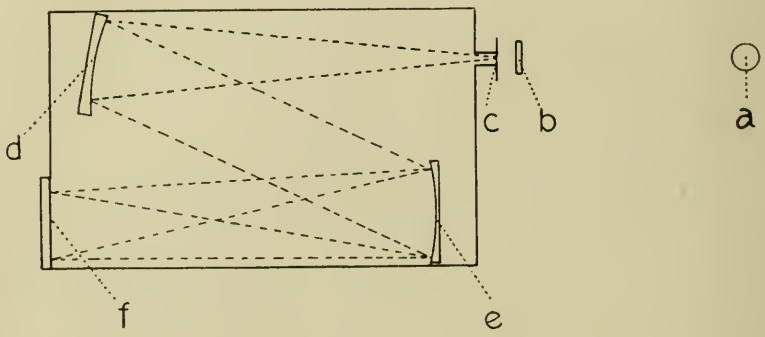
bath. Since this increase is quite marked in the case of some dyes, it was hoped that in this way commercial plates could have their speed increased, and, at the suggestion of Dr. P. W. Merrill, a study was made at the Bureau of Standards of the influence of ammonia on commercial orthochromatic and panchromatic plates.

SENSITOMETRY.

Three methods of sensitometry were used: first, the three-color screen method; second, the spectrograph method; and third, the Hurter and Driffield method.

The first method, based on Abney's method,[3] which, however,

FIG 1.



a, lamp source: *b*, yellow glass; *c*, slit; *d*, concave mirror; *e*, diffraction grating; *f*, plate to be tested.

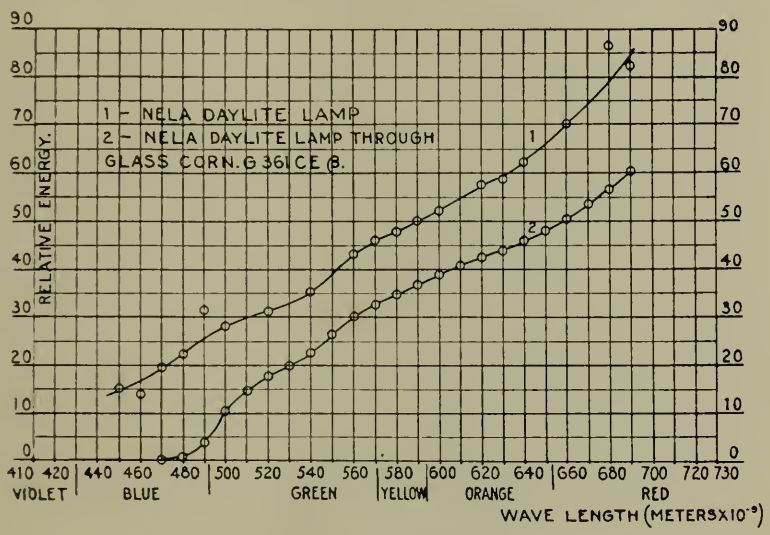
was used only as a qualitative method at first, consists of exposing the plates to a constant light source (usually a nitrogen-filled tungsten lamp corrected by color screens so as to have an energy distribution similar to daylight) behind a so-called trichromatic sensitometer plate. This plate is a neutral screen having four strips of squares of increasing density, each square having twice the density of the preceding. One of these strips is left white, while on the others are placed a red, a green, and a blue filter intended to be of the same luminosity and mutually exclusive. The plates to be tested are thus exposed to varying intensities of white, red, green and blue light.

The second method avoids the difficulty of obtaining filters transmitting pure spectral colors, by exposing the plate in a spectrograph.

[3] *Phot. Jour.*, June, 1895; Eder, "Phot. Korr.," 1903, p. 426. Chapman Jones, *Photo. Jour.*, 1901, 256.

The apparatus (Fig. 1) consists of a concave grating of 50 cm. radius with 20,000 lines per inch, mounted in parallel light with a 100-watt "daylight" tungsten lamp on 110-volt A. C. circuit as a source. For use with color sensitive plates a piece of yellow glass (7 mm. thick, Corning G 351 CE) barely transmitting the hydrogen blue line with wave-length 4861A was placed in front of the slit to cut out the second order blue. The region photographed was from about 4800A to the limit of sensitivity of the plate. A pair of cross-hairs just in front of the plate at

FIG 2.



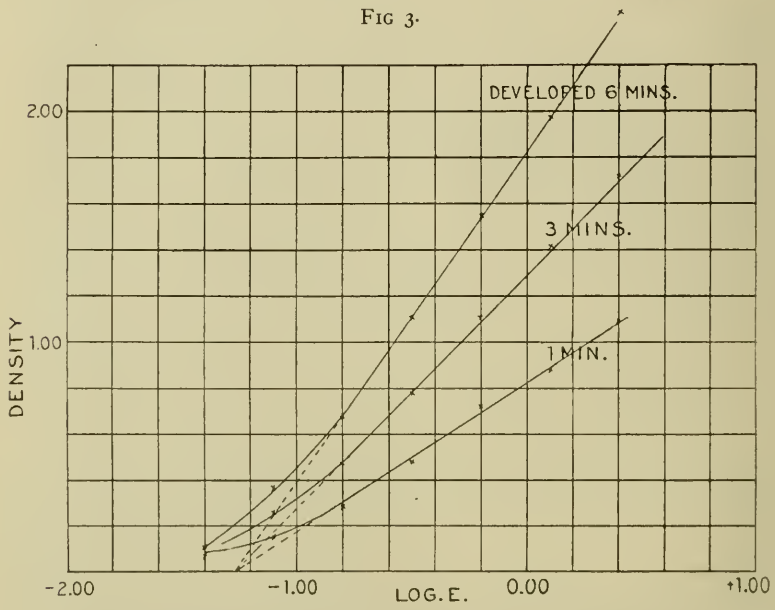
the position of the red line of hydrogen (wave-length 6563A) and of the blue line (4861A) served as reference marks. Fig. 2 gives the energy distribution of the lamp and screen combination. The energy was determined in the spectrophotometric laboratory, visually on a König-Martens Spectrophotometer, by a substitution method of comparison with a radiometrically calibrated Mazda lamp.

The photographic densities were measured on a Hartmann Microphotometer. This method gives immediately the sensitivity of the plate to all parts of the spectrum; but since, during the course of the work, minor changes (change of slit, resilvering of mirror, etc.) were made, the exposure times on different sets of plates were not always equivalent.

Furthermore, since the plates were of different kinds and showed markedly different rates of development, they were, in this part of the work, developed by tray until they showed the amount of fog allowable in plates to be used in general photography. The density of the silver deposit obtained depends on the time of development, so that in the curves obtained the shapes (maxima and minima) are the really important parts and the density is only approximately a measure of the speed.

The method generally adopted for the measurement of the

FIG 3.



Ilford special rapid panchromatic (5630N). Untreated; no filter; speed, 4.45.

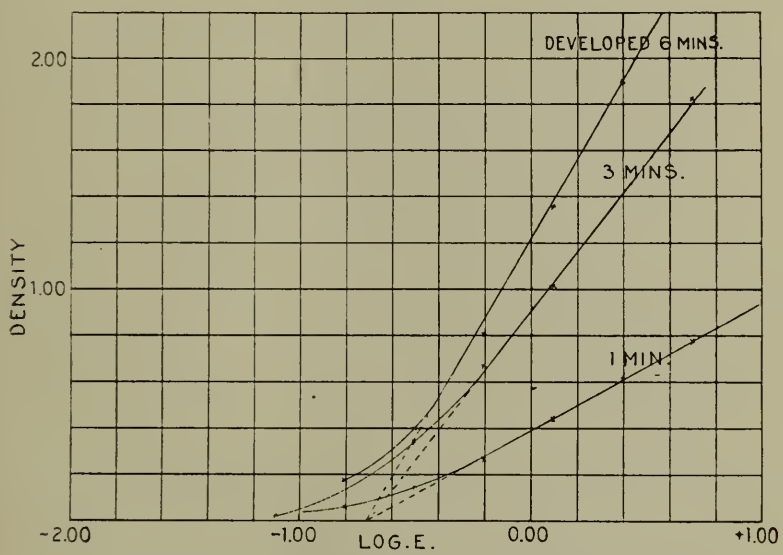
speed is that of Hurter and Driffield.[4] Specimens of the plate to be tested are exposed for the same time, behind a sectored wheel, to a standard light source. The transmissions, T, of the images obtained are measured and their densities, defined as $-\log T$, are plotted as ordinates and the logarithm of the time of exposure, E, as abscissas.

The curve so obtained is known as the characteristic curve of the plate. It consists of three parts: the first part is concave

[4] Hurter and Driffield, *Jour. Soc. Chem. Industry*, May, 1890, p. 455.

upward, the second is a straight line and the third is concave downward. Prolong the straight line part of the curve until it intersects the axis of abscissas. The numerical value of the exposure at the point of intersection is known as the inertia, *i*, of the plate and the speed is defined as $1/i$. Hurter and Driffield showed that this inertia of a plate is independent of the kind of developer used (except for strong pyro and for the presence of free bromide) and of the time of development (see Figs. 3 and 4). Free bromides, either in the film or in the developer, shift the point of

FIG 4.



Ilford special rapid panchromatic (5630N). Treated; no filter; speed, 18.2.

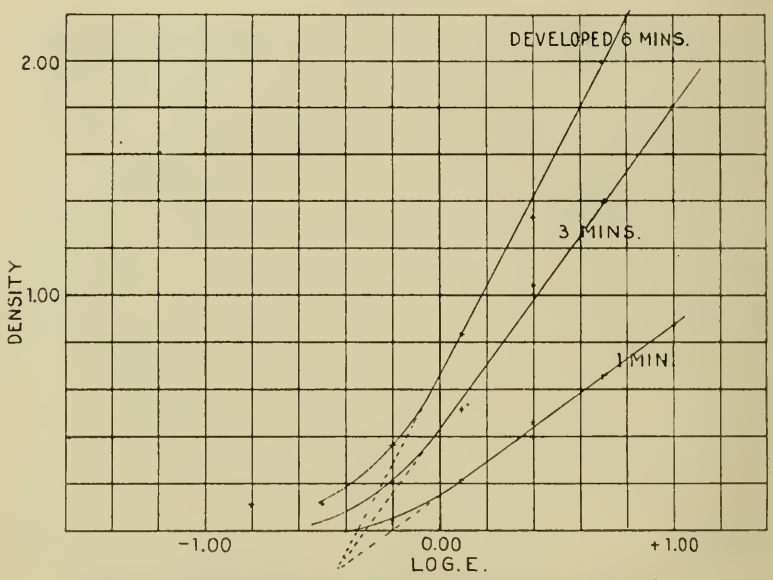
intersection of the straight line portions of the curves to a point below the axis. The plates for which Fig. 5 gives the characteristic curves contain free bromide in the emulsion.

The Hurter and Driffield speeds for several ammoniated and unammoniated plates were obtained, using an apparatus designed and built by Mr. R. Davis of the Bureau of Standards. The light source (a calibrated tungsten lamp) is corrected for daylight, and means are provided for accurately controlling the current through the lamp, the speed of the sectored disc and the total time of exposure.

PROCEDURE.

A series of Cramer Spectrum Process and Ilford Special Rapid Panchromatic plates were bathed for four mintes at 16° to 18° C. in water containing increasing amounts of ammonia, and were then exposed in the spectrograph. Both Metol-Hydroquinone and Pyro developers were used. It was soon found that the plates showed fog in development unless they were kept cool while drying and were dried rapidly. The plates showed a progressive increase in speed with increase in ammonia concentration

FIG 5.



Cramer spectrum process (1439). Treated; Wratten "F" filter; speed, 1.88.

until, with a bath containing 4 c.c. of ammonia water (containing 20 per cent. NH_3) in 100 c.c. distilled water, the plates began to fog so badly in development as to be useless.

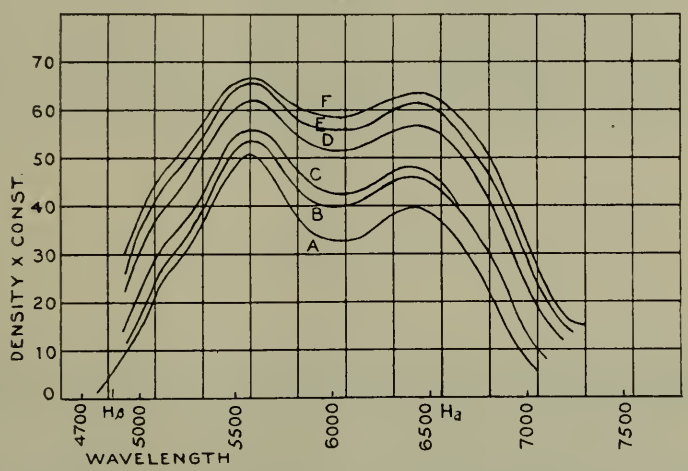
The ammonia was then added to water-alcohol mixtures of varying concentrations. The plates bathed in the alcoholic ammonia did not have their sensitivity increased as much as in the corresponding water baths, but were very much cleaner working. Seventy-five parts of water to twenty-five of ethyl-alcohol gave the best results, and this proportion was adhered to thereafter. Sometimes the plates showed a slight network of fog (mottling)

similar to the drying marks shown when plates are dipped (not soaked) in alcohol to hasten drying. Washing in 95 per cent. alcohol for 20 or 30 seconds after the ammonia bath prevented this, but this final wash is not usually necessary, especially if the plates are not forced in development.

Fig. 6 gives the spectral sensitivity curves of a series of Cramer Spectrum Process plates in baths containing $^1/_{40}$, $^1/_{10}$, ½, 1 and 3 c.c. of 20 per cent. NH_3 ammonia water to an alcohol-water mixture of 25 parts of alcohol and 75 parts of water.

Three to 3½ c.c. of the strong ammonia to 75 c.c. of water and

FIG 6.



Cramer spectrum process (1439). *A*, untreated; *B*, $^1/_{40}$ c.c. ammonia; *C*, $^1/_{10}$ c.c. ammonia; *D*, $^1/_2$ c.c. ammonia; *E*, 1 c.c. ammonia; *F*, 3 c.c. ammonia; 75 c.c. water; 25 c.c. alcohol. Same exposure and development.

25 c.c. alcohol was adopted as the combination to be used, and except for a few trials on various plates, the plates were all treated with this same mixture.

The time of bathing, 2, 4, or 6 minutes, had no appreciable effect, provided that the film was bathed long enough to get thoroughly soaked. Four minutes was the time used for bathing in all subsequent experiments.

For a study of the keeping qualities of the plates, a number of Cramer Spectrum Process and Ilford Panchromatic plates were treated and samples of the treated plates exposed and developed after being stored for various lengths of time. The Cramer plates showed deterioration after a week but were still usable.

The Ilford plates were useless after 3 or 4 days. The plates bathed without the use of alcohol deteriorated more rapidly.

The bath of 3 to 3½ c.c. of ammonia water (20 per cent. NH_3), 25 c.c. of alcohol and 75 c.c. of water is recommended. Three and one-half c.c. of ammonia water to 100 c.c. of water is used where the maximum increase of sensitivity is desired, but the plates are much more susceptible to fog in development and must be used within a few hours of drying. Development should be carried out, using the Wratten Safelight No. 3 and over-development carefully guarded against.

ORDINARY PLATES.

As is well known, the speed of the silver halide emulsion can be increased by treatment before it is flowed on the plate. This treatment, known as "ripening," is usually either to keep the emulsion at a high temperature for some time or to add ammonia. This ripening by ammonia is effective even after the plates are ready for use.[5]

On ripened plates such as the Seed 30 and Central Special, and on the Seed 23, there is no appreciable increase in speed when they are bathed in ammonia. In some cases there is rather a slight decrease in speed. On one plate known to have been ripened by the ammonia process before coating (Central Dry Plate Co.) which, however, was not fresh, this increase in speed on subsequent bathing in ammonia was quite apparent.

Microscopic examination of the treated and untreated plates showed no difference in the size of the grain.

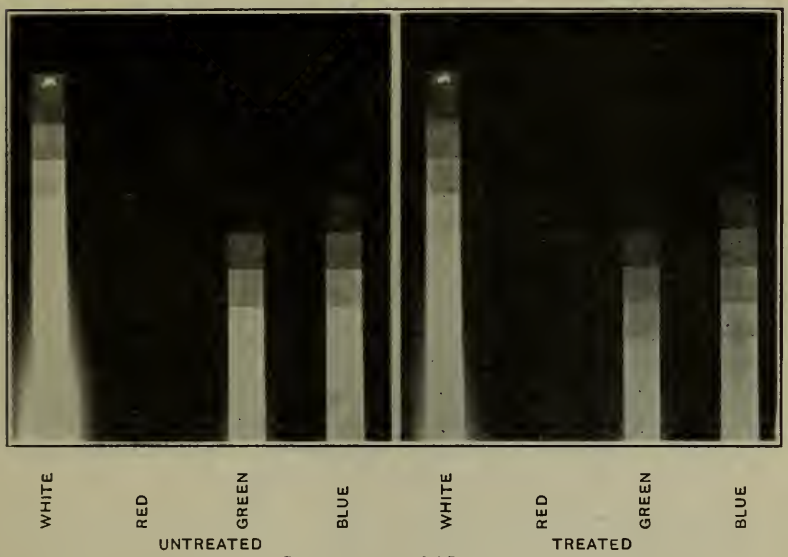
ORTHOCHROMATIC PLATES.

A number of plates sensitive to the green and yellow were tried. Most of them showed no appreciable change in sensitivity. Some had the sensitivity decreased, *e.g.*, Cramer Commercial Isonon. The sensitivity of the Seed Aero Ortho was increased slightly.

Fig. 7 is a print from treated and untreated Cramer Commercial Isonon negatives obtained through the tricolor sensitometer plate. Fig. 8 is a similar set on the Seed Aero Ortho. It will be noted that the change in sensitivity can be observed in all the strips.

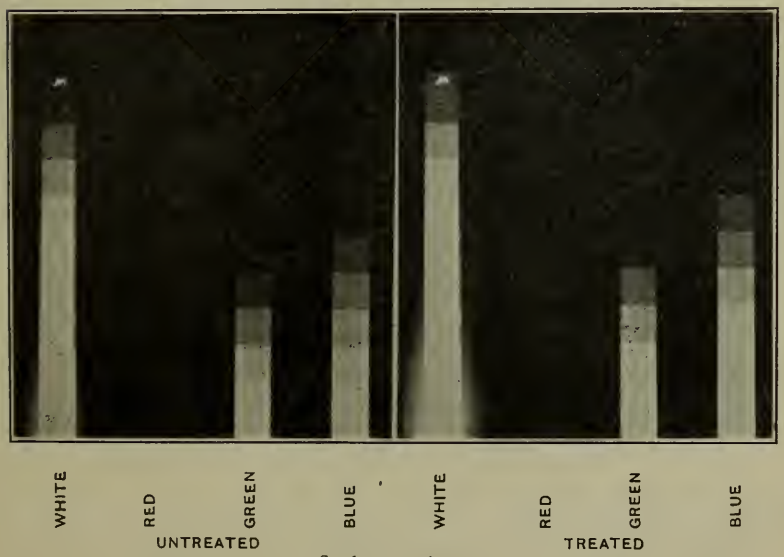
[5] Eder, "Handbuch," iii, p. 63.

FIG 7.



Cramer commercial Isonon.

FIG 8.



Seed aero ortho 5.

The Cramer "Trichromatic" showed an increase in sensitivity comparable to that observed in the Spectrum Process.

Treatment of Eastman and of Ansco N. C. films, which are orthochromatic, showed no change larger than the differences attributable to experimental errors.

PANCHROMATIC PLATES.

Every panchromatic plate tried showed remarkable increase in speed. The very fast plates, several of which were developed only recently in response to the need for fast color sensitive plates for aerial photography, showed a somewhat smaller increase than the slower and process plates.

The plates examined were:

Cramer Spectrum Process;
Ilford Panchromatic (Special Rapid);
Five of the Eastman Special Experimental Panchromatic plates;
Wratten and Wainwright Special Red Sensitive;
Wratten and Wainwright R. F. C. Panchromatic;
Wratten and Wainwright Panchromatic;
Wratten M;
Cramer Spectrum No. 11;
Cramer G D I, G D II, G D III;
Central Experimental Panchromatic.

Wherever possible several different emulsions were used.

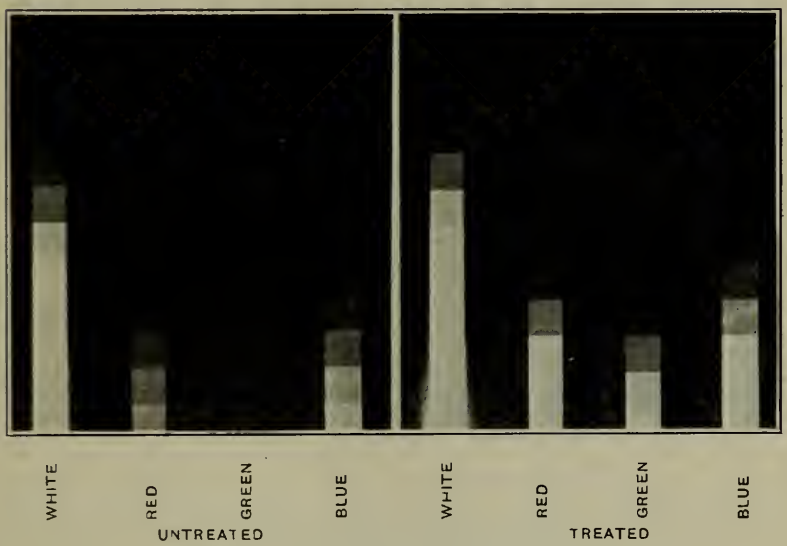
Figs. 9, 10, and 11 are prints from pairs of Wratten and Wainwright Special Red Sensitive, one of the Eastman Experimental emulsion and Ilford Panchromatic plates. The three sets of prints were exposed and developed exactly alike on Artura Iris paper. Even though the paper cannot reproduce all the gradations of the original negative, they do give fairly well the relative speeds of these three brands of plates and show quite well the great increase in speed effected by the ammonia treatment.

This sensitometer plate method gives the relative speeds of plates towards filters, but since the filters do not transmit pure spectral colors (the blue transmits a band in the red and the transmission of the three filters overlap) more can be learned of the color sensitivity from the spectrograph curves.

Fig. 12, a print from a treated and an untreated Spectrum Process Plate, shows the sensitivity of the plate to each wave-length.

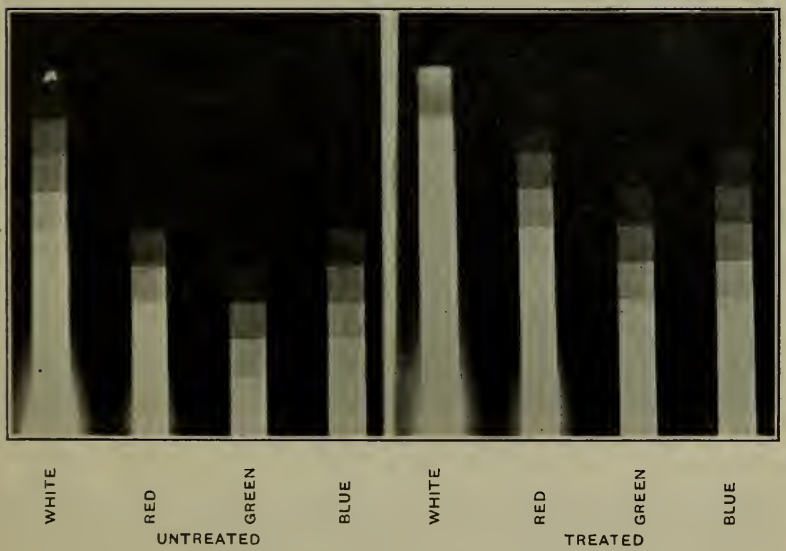
Fig. 13 gives the spectral sensitivity curves obtained with the

FIG 9.



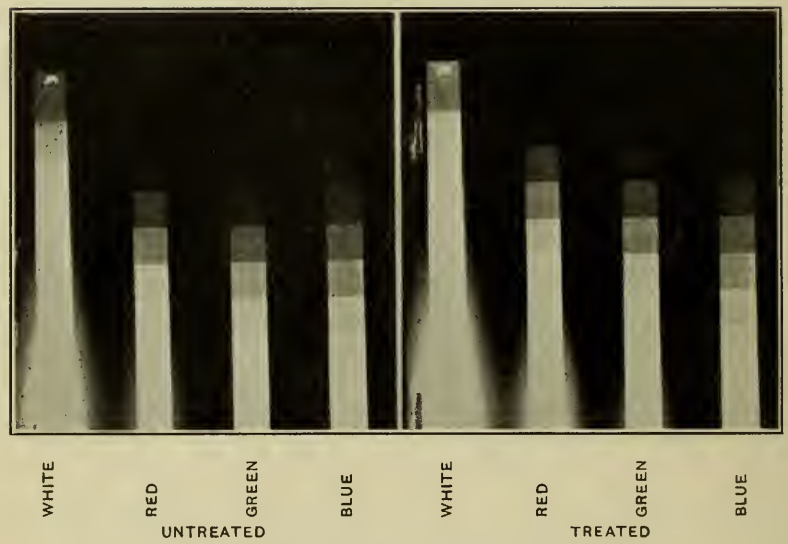
Wratten & Wainwright special red sensitive.

FIG 10.



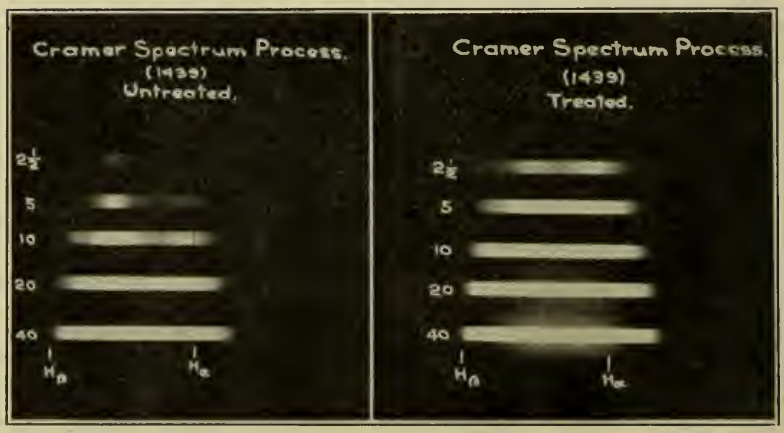
Eastman experimental panchromatic EIV.

FIG 11.



Ilford special rapid panchromatic 56418.

FIG 12.



Cramer spectrum process (panchromatic).

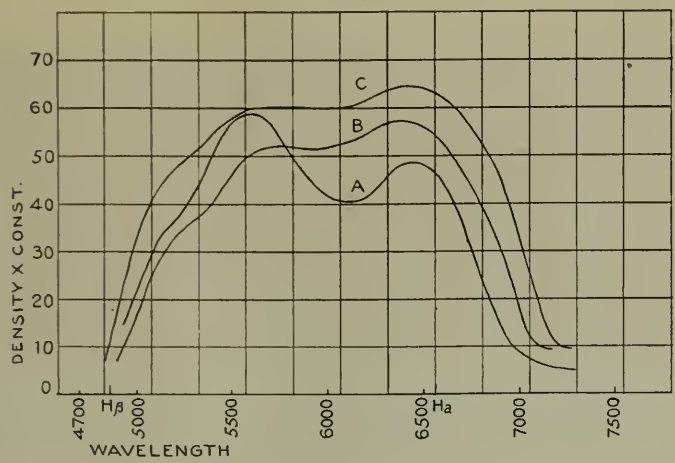
Spectrum Process plate: 5- and 10-second exposures on the treated and 10 seconds' exposure on the untreated plate.

Fig. 14 gives the curves for one of the Eastman Kodak Com-

pany's special experimental Panchromatic Plates. Both curves are for 10-second exposures.

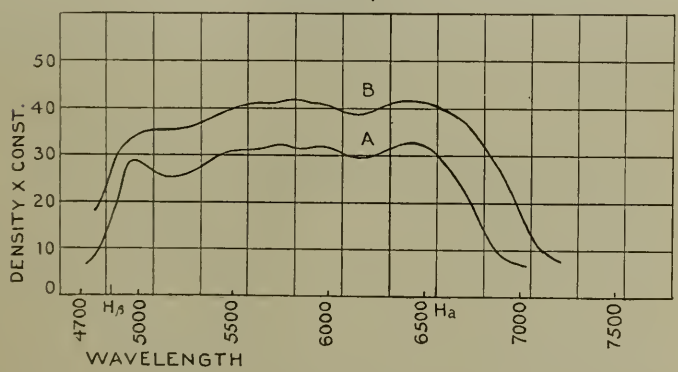
In Fig. 15, curve *A* is for the 10-second exposure on the un-

FIG 13.



Cramer spectrum process (1439). *A*, untreated, 10-second exposure; *B*, treated, 5-second exposure; *C*, treated, 10-second exposure.

FIG 14.



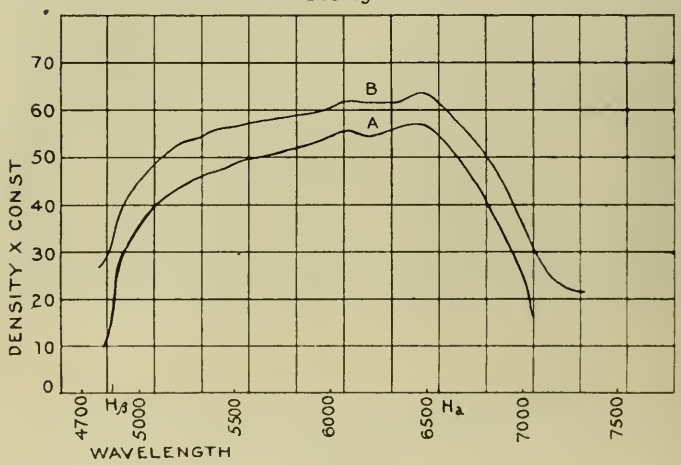
Eastman special experimental panchromatic (EIV 2165D). *A*, untreated, 10 seconds exposure *B*, treated, 10 seconds exposure.

treated Ilford Panchromatic plate. Curve *B* is for the 5-second exposure on the treated plate.

One of the most striking changes produced by the ammonia treatment was the action on old panchromatic plates. A Wratten and Wainwright plate marked "use before September 15, 1915," was exposed on October 21, 1918, in the spectrograph. As was

to be expected, the plate was badly fogged on the edges and the sensitivity of the emulsion was much below that of a fresh plate. Treatment with ammonia brought the sensitivity up to an even greater value than that possessed by a fresh plate (see Figs. 16 and 17).

FIG 15.



Ilford special rapid panchromatic (56418). *A*, untreated, 10 seconds exposure; *B*, treated, 5 seconds exposure.

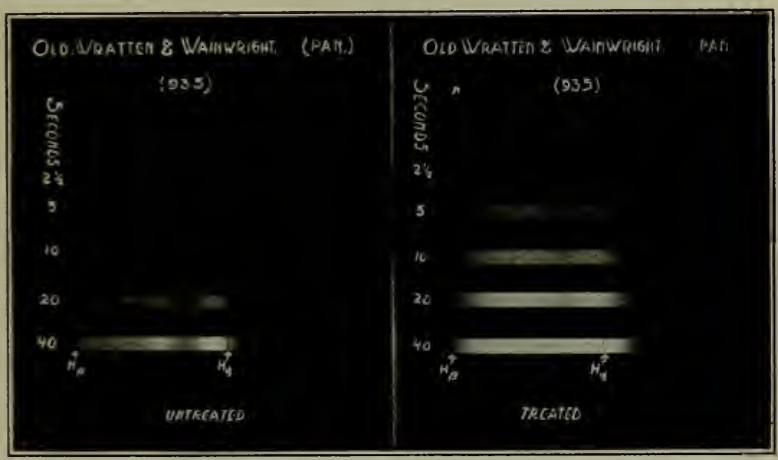
The Hurter and Driffield curves for some of these plates gave the following values for the speed:

	Untreated	Treated
	White Light	
Cramer Spectrum Process (1439)	10.2	25.1
Eastman Experimental Panchromatic IV d..	12.6	17.7
Ilford Special Rapid Panchromatic 5630 N..	4.45	18.2
Standard Orthonon	23	
	Minus Blue Filter	
Eastman Experimental Panchromatic 2199..	1.91	4.37
Ilford Special Rapid Panchromatic 56,416..	4.37	13.5
	F Filter	
Cramer Spectrum Process (1439)	0.49	1.88
Eastman Experimental Panchromatic IV d.	0.57	2.18

The figures give the absolute speeds of the plates to white light and through the Wratten Minus Blue and F Filters on the Hurter and Driffield scale. The value for the speed of the Standard Orthonon plate to white light obtained on the same apparatus is given for comparison. The Minus Blue, a deep yellow filter, cuts out all the blue and violet light, while the F, a deep red, transmits only the long red wave-lengths.

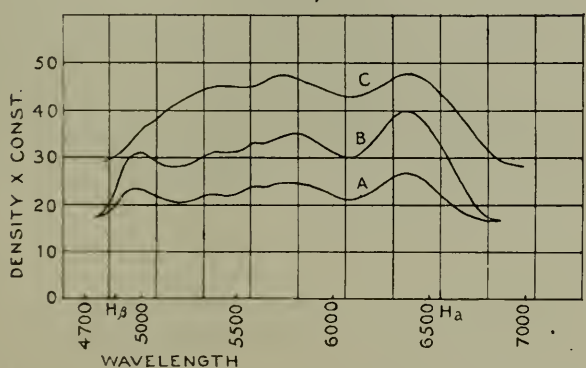
These figures show the remarkable increase in speed of the plates, particularly in the long wave-length region. Thus the Cramer Spectrum Process plates are increased in speed 150 per

FIG 16.



Wratten & Wainwright panchromatic. Expiration date, September 15, 1915. Used October 21, 1918.

FIG 17.



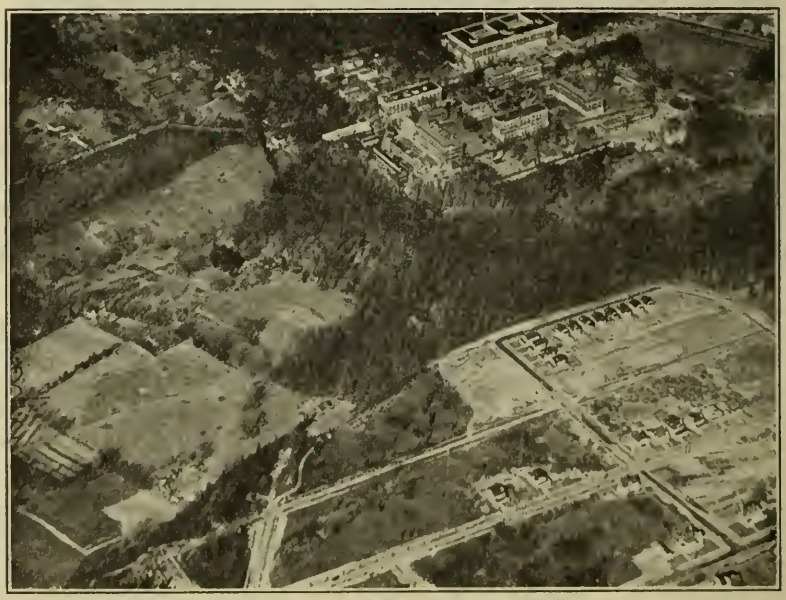
Wratten & Wainwright panchromatic (935). Expiration date, September, 1915. Used, October, 1918. *A*, untreated, 10 seconds exposure; *B*, untreated, 20 seconds exposure; *C*, treated, 10 seconds exposure.

cent. to white light and nearly 400 per cent. to the red. Through the Minus Blue filter one of the Ilford plates is increased 300 per cent.

These plates were used in experiments in airplane photog-

raphy, where for photographing through the haze a fast red-sensitive plate is necessary. Fig. 18 is a set of prints from the Ilford plates. Prints *a* and *b* were printed for the same time from the untreated and treated plates. Print *c* is from the untreated negative timed to give the best print. The negatives were given the same exposure in the air and were exposed within a few seconds of each other through the Minus Blue filter.

FIG. 18a.



AMMONIATED PLATE. PRINTED 21 SECONDS.

Hypersensitized Ilford plate. $\frac{1}{30}$ second exposure. Minus blue filter. Oblique from 4,000 feet.

The increased speed of the treated plate is apparent. It will be seen, also, that the treated plate is less contrasty and gives much better detail in the shadows.

Fig. 19*a* is from a Seed 30 plate used with no filter at an altitude of 17,000 feet on a slightly hazy day. Fig. 19*b* shows the same scene taken on a treated Spectrum Process plate through the A filter. The pictures were taken simultaneously in a multiple lens camera. The increased haze penetration obtainable by the use of the red filter is clearly shown.

FIG. 18b.

UNTREATED PLATE. PRINTED 21 SECONDS.

Ilford panchromatic plate. $\frac{1}{130}$ second exposure. Minus blue filter. Oblique from 4,000 feet.

FIG. 18c.

UNTREATED PLATE. PRINTED 8 SECONDS.

Ilford panchromatic plate. $\frac{1}{130}$ second exposure. Minus blue filter. Oblique from 4,000 feet.

ACTION ON MINIMA.

On every plate which had an irregular curve of spectral sensitivity, the minima were raised and in many cases smoothed out entirely. For example, note the minima at 6100A (Fig. 13), at 5200A and 5850A (Fig. 14), and at 5200A and 6100A (Fig. 17). This property of the ammonia treatment adds greatly to the value

FIG. 19a.

SEED 30 PLATE, F/11. NO FILTER.
30° oblique from 17,000 feet. Hazy day. $\frac{1}{100}$ second exposure. Taken simultaneously with 19*b* in a multiple lens camera.

of the plates in the photography of spectra, especially as the sensitivity is extended some 200 Ångström units further into the red at the same time. The bad effect of a minimum is, however, smoothed out to some extent in ordinary photography through filters.

PLATES WITH KNOWN DYESTUFFS.

The difference in behavior between the ordinary and orthochromatic plates and the panchromatic plates shows clearly that

the sensitivity increase dealt with here is not that observed by Eder, which is due to "ripening," but is an action associated with the dyestuff.

The effect of the ammonia is to increase the sensitivity of the emulsion to the incident light and not to increase the developability of a latent image already formed, since a plate treated with

FIG. 19b.

HYPERSENSITIZED CRAMER SPECTRUM PROCESS PLATE. F 4.5. WRATTEN A FILTER.

30° oblique from 17,000 feet. Hazy day. $\frac{1}{100}$ second exposure. Taken simultaneously with 19*a* in a multiple lens camera.

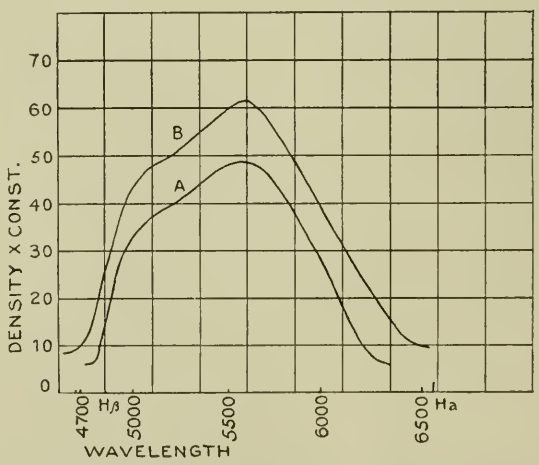
ammonia after exposure but before development showed no increase in sensitivity. That the action is not due to the alkalinity of the bath is shown by the fact that bathing in a solution of sodium hydroxide having the same concentration of OH ions had no effect on the speed of the plate.

Part of the increase in speed is, probably, due to the fact that some of the dyestuff in the gelatine film is washed out and

its screening effect diminished. The ammonia bath becomes colored with use and a color difference is observed between the untreated and treated plate before development.

The pinaverdol dyes sensitize for the green and yellow and an orthochromatic plate containing one of this series of dyes has the sensitivity increased by the ammonia treatment. Fig. 20 is a plate made up by the Cramer Dry Plate Co., using pinaverdol Pv. I., made by the Bureau of Chemistry, and marked by Cramer "similar to Trichromatic." The Trichromatic plate has the sensitivity curve of a pinaverdol dyed plate and Fig. 21 gives the curve before and after ammonia treatment.

FIG 20.



G D IV. PvI (similar to trichromatic); *A*, untreated, 10 seconds exposure; *B*, treated, 10 seconds exposure.

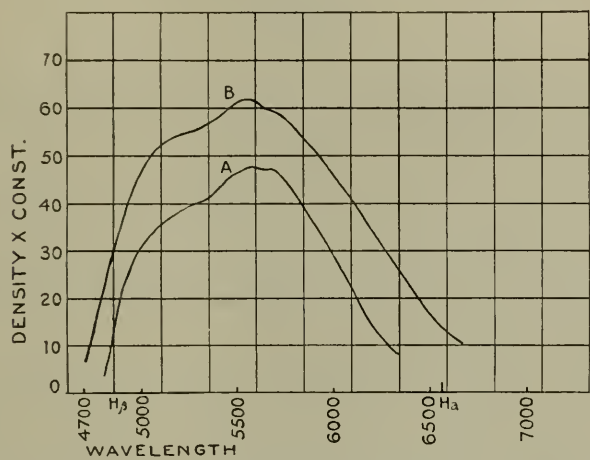
Mixtures of pinaverdol and pinacyanol are the dyes usually used in the preparation of panchromatic plates intended for spectrum photography. The mixture of these two dyes alone leaves a strong minimum at about 6100A. The ammonia treatment smooths out the minimum. In many plates intended for general photography other dyes are added to sensitize in this region (see Fig. 17).

Fig. 22 gives curves for a plate (similar to their Spectrum Plate) made up by the Cramer Co., using a mixture of the Bureau of Chemistry's pinacyanol, Pc. XII., and pinaverdol, Pv. I. It

will be noted that the addition of pinacyanol lowers the maximum due to the pinaverdol.

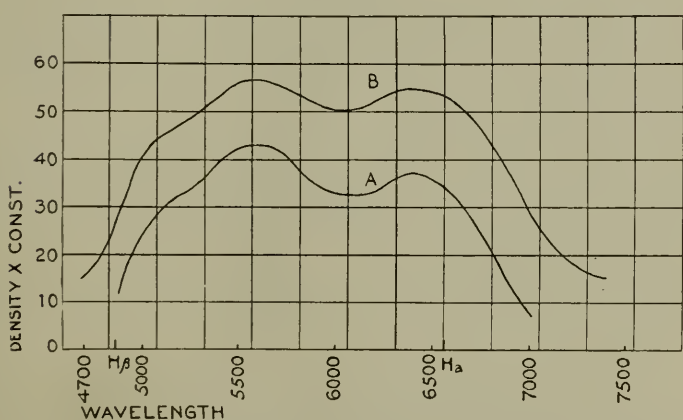
The dyes used in sensitizing are nearly all basic dyes, and it is not probable that the ammonia changes the dye itself. On the

FIG 21.



Cramer trichromatic, No. 21. *A*, untreated, 10 seconds exposure; *B*, treated, 10 seconds exposure.

FIG 22.



G D III. PcXII and PvI; *A*, untreated, 10 seconds exposure; *B*, treated, 10 seconds exposure.

addition of ammonia to the dye solution before bathing, there is no color change. It is possible that the solvent action of the ammonia on the silver halide facilitates the reaction between the

dyestuff and the silver salt, in addition to its softening effect on the gelatin. This, however, does not account for the raising of the minima. It is possible that there is the formation of a $AgNH_3Cl$ + Dyestuff molecule with a photosensitiveness slightly different from that of the original molecule.

SUMMARY.

Since ammonia, when added to the dye bath in preparing bathed plates, increases the sensitizing action of the dye, its action on commercial plates was investigated.

In the course of the work three methods of sensitometry were used. Of these, one was used as a first qualitative test; the second, the spectrograph method, was used to study the effect of the ammonia on the sensitivity of the plate to each wave-length; the third, the Hurter and Driffield method, gives the absolute value of the speed of the plate.

It was found that by bathing commercial panchromatic plates in a solution of 25 c.c. ethyl-alcohol, 75 c.c. water, and 3 c.c. of strong ammonia water (20 per cent. NH_3) for four minutes at 18° C. and drying rapidly, the speed to white light is increased 100 per cent. in nearly all cases, and the sensitivity in the red extended one hundred or more Ångström units. The speed in the red is increased, in many cases, 400 per cent. If the plates be bathed without the alcohol (100 c.c. water, 3½ c.c. ammonia water) the speed is still more increased, but the plates should be used immediately after drying.

Ordinary plates do not have their sensitivity appreciably changed. Most brands of orthochromatic plates are not improved, although one, the Cramer Trichromatic, showed the same increase as the panchromatic plate.

My thanks are due to Dr. J. S. Ames for his supervision of the present investigation and for valuable advice rendered during many conferences.

The energy distribution of the light source in the spectrograph was determined by Mr. E. P. T. Tyndall and Mr. H. J. McNicholas of the spectrophotometric laboratory. I am also indebted to Mr. R. Davis and Mr. F. M. Walters, Jr., through whose help the Hurter and Driffield curves were obtained, and to Dr. C. C. Kiess, under whose direction and coöperation most of the work was done.

WULFENITE: ITS CONCENTRATION AND SEPARATION FROM BARITE.*

BY

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During the past two years a number of articles concerning the mining and concentration of molybdenum ores have appeared in the technical and mining journals. These, however, have been confined almost wholly to the description of methods employed in the treatment of molybdenite (MoS_2) ore. This has been chiefly due to the fact that there are larger deposits of this mineral in the United States than of wulfenite ($PbMoO_4$), the other commercial molybdenum ore. The advent of flotation and its adaptability to the concentration of molybdenite resulted in the United States producing, during the war and since, more molybdenum than any country in the world. Several methods of concentrating molybdenite ores have been used with varying success, depending upon the grade and character of ore treated. The methods which have been successful on molybdenite include rolling and screening processes, surface tension, and oil flotation processes and electrostatic methods. Oil flotation has proven so successful, especially on low-grade material, that it is being used almost exclusively. As a consequence, it would be safe to say that over 80 per cent. of the molybdenum produced came from molybdenite concentrates obtained by oil flotation, with an average extraction of 70–80 per cent. of the MoS_2 with a ratio of concentration of 100 to 1, depending upon the grade of product made. Colorado ranks first in the United States as a source of molybdenum, having produced during the year (1918) 665 tons of concentrates, figured on a basis of 90 per cent. molybdenum sulfide valued at $1,436,400.[1] This, when compared with the world production of between 250 and 300 tons (Mo) for 1915, indicates the importance of Colorado as a source of molybdenum from molybdenite ores. The principal working

* Communicated by the Director of the Bureau of Mines.

[1] Fifteenth Biennial Report of the Bureau of Mines, State of Colorado, 1917–1918, p. 107.

deposits in Colorado occur at Climax, Summit County, and near Empire, Clear Creek County. Other commercial deposits being worked at the present time occur at Questa, New Mexico; Pitkin, Colorado, and near Nogales, Arizona. Colorado, Arizona, New Mexico, California, Montana and Washington constitute the principal states where either molybdenite or wulfenite, or both, occur. These, as well as the minor deposits of molybdenum ores in the United States, are described by F. W. Horton.[2]

Little has been published concerning wulfenite ores and their concentration and, therefore, it is desired to emphasize in this paper the methods employed in the ore dressing of wulfenite ores—especially the separation of this mineral from barite gangue. Although there are several molybdenum minerals found in this country besides molybdenite and wulfenite, these two are the only ores of molybdenum that are considered of any commercial importance; the others being rare with one exception, molybdite ($Fe_2O_3.3MoO_3.7\frac{1}{2}H_2O$), which commonly occurs with molybdenite as an alteration product, and the recovery of which is difficult by the flotation process.

WULFENITE.

Horton[3] describes the mineral as follows:

> Wulfenite is a molybdate of lead ($PbMoO_4$) and theoretically contains 26.15 per cent. of molybdenum and 56.42 per cent. lead. It is a heavy, brittle, subtransparent to subtranslucent mineral with a resinous or adamantine lustre, and is generally of a wax or orange-yellow color. It may, however, be siskin and olive green, yellowish-gray, brown grayish-white to nearly colorless, or orange to bright red. Its hardness is 2.75 to 3 and its specific gravity is 6.7 to 7. It has a subconchoidal fracture and a white streak. In planes parallel with its crystal pyramid faces it has a smooth cleavage, but in other directions the cleavage is less distinct. It crystallizes in the tetragonal system with pyramidal hemihedrism. The crystals are commonly square and tabular and are sometimes extremely thin, with a vicinal pyramid replacing the basal plane. Less frequently the crystals are octahedral or prismatic, the prismatic faces showing the hemihedrism characteristic of the mineral.

QUALITATIVE TESTS.

1. One of the best tests is to fuse some of the pulverized ore with sodium or potassium carbonate to which a small amount of

[2] Horton, F. W., "Molybdenum, Its Ores and Their Concentration." Bulletin 111, Bureau of Mines (1916).

[3] *Loc. cit.*, p. 9.

potassium or sodium nitrate has been added. The fusion is treated with water, heated and filtered; the filtrate is acidified with HCl and boiled several minutes to expel all carbon dioxide. Some ammonium or potassium thiocyanate is added, followed by zinc; if molybdenum is present, a bright cherry-red color rapidly develops that will disappear only on prolonged standing in the presence of zinc. If hydrogen peroxide is added to the solution immediately after the cherry-red color has developed, the color disappears but returns as soon as the peroxide has been reduced. When only small amounts of molybdenum are present, if the solution is shaken with a small volume of ether after the thiocyanate and zinc have been added, any color in the liquid will be extracted by the ether and intensified as a golden-brown in the ether ring that forms at the top of the liquid on standing. This makes visible a color that before may have been imperceptible. Should the fusion be imperfect with an extraction of iron in the leach from the fused carbonates, a cherry-red color will immediately develop on the addition of the potassium or ammonium thiocyanate to the solution. On adding the zinc, however, the color due to iron disappears, and, unless a large quantity of iron has been brought into solution, this color will completely disappear prior to the development of any color due to molybdenum. If this color reaction of iron and its disappearance on addition of zinc are borne in mind, the above test for molybdenum is excellent.[4]

2. With the blowpipe on charcoal, wulfenite decrepitates and fuses, giving a yellow coating of lead oxide on the charcoal, and, when heated with soda ash on charcoal, it yields metallic lead; with a salt of phosphorus, it gives a yellowish-green glass in the oxidizing flame, which becomes dark green in the reducing flame; with borax in the oxidizing flame, it gives a colorless glass which in the reducing flame becomes opaque black, or dirty green.

3. A pinch of powdered molybdenum ore on a porcelain lid, if moistened with a few drops of nitric acid so as to make a paste, and heated nearly to dryness, then followed by 0.5 c.c. of concentrated sulphuric acid, will, after being heated to fumes and allowed to stand, produce a blue color when breathed upon; a drop of alcohol added at this point will hasten this color reaction. The color will disappear on heating, but if allowed to stand for

[4] Horton, *loc. cit.*, p. 40.

some time will reappear on cooling. Water will also destroy the color.

4. An alkaline solution of a molybdate free from iron, after acidifying with acetic acid, will, on the addition of potassium ferrocyanide or tannic acid, produce a deep red to brown coloration. Pyrogallol, under similar conditions, will give an orange coloration. None of the tests, however, are as sensitive as the ammonium or potassium thiocyanate test previously given.

OUTLINE OF METHODS FOR DETERMINING MOLYBDENUM IN WULFENITE ORES.

Wulfenite, when powdered sufficiently fine, is completely soluble in a mixture of hydrochloric and sulphuric acids, or nitric and sulphuric when taken to fumes. If desired, a mixture of the three acids may be used; only rarely will the residue from such acid treatments contain any undissolved molybdenum. After cooling the hot sulphuric acid, water is added; and then, without filtering off the insoluble matter, an excess of ammonium hydroxide. Boil, filter and wash well with hot water. Redissolve the precipitate in dilute sulphuric acid and reprecipitate, boil, filter and wash. The filtrate will be clear and colorless, and the molybdenum will be found in solution as ammonium molybdate. The filtrate is then acidified with HCl, and ammonium acetate added, followed by a few cubic centimetres of acetic acid. Lead acetate will precipitate from such solution lead molybdate as a white precipitate. Chromium, vanadium, tungsten and phosphorus will, however, interfere with this latter precipitation, and if their presence is known, they must be removed before the precipitation of molybdenum is made. Phosphorus is usually precipitated along with the iron group; however, to insure this precipitation it is advisable to add a few cubic centimetres of ferric chloride solution before adding the ammonium hydroxide. Chromium and tungsten are rarely found associated with molybdenum ores. Molybdenum is separated from vanadium by passing H_2S into a slightly acid solution under pressure.

The above acid method of decomposition forms the basis for the successful quantitative determination of molybdenum. At the point where the lead acetate is added to the acetic acid solution, a standard lead acetate solution can be run from a burette until a test drop gives no color change with a drop of tannic acid

indicator solution. This method is the reverse of the ammonium molybdate method for the determination of lead. Better results are obtained, however, if the lead molybdate precipitate is weighed. If desired, the molybdenum can be determined, after making the ammoniacal filtrate acid with surphuric, by passing through a Jones reductor and titrating with a standard permanganate solution. The details for the successful determination of molybdenum in ores, as outlined above, and the removal or determination of the interfering elements, have been definitely established and carefully worked out. This will be described in a Bureau of Mines technical paper.[5]

SOURCE AND IMPORTANCE OF WULFENITE.

Up to 1915, wulfenite ores constituted the principal source of molybdenum in this country. Horton [6] states that:

> Wulfenite ores from Arizona have supplied the larger part of the molybdenum produced in this country to 1915, and on account of the ease with which they are concentrated they should prove a strong competitor of molybdenite for markets that do not require concentrates with a high molybdenum content.

The deposits in Arizona are largely confined to the four southern counties, Cochise, Pima, Pinal and Yuma, with a few in Gila, Maricopa and Yavapai Counties. Besides the deposits occurring in Arizona, wulfenite has been reported in several scattered localities throughout the Western States of Nevada, New Mexico, Utah, California and Montana. The location, geology, extent and development of all these wulfenite deposits are given by Horton.[7] Several of these deposits of wulfenite might be worked at a profit and would have a better chance to compete with the molybdenite market if more were known regarding the metallurgical treatment of the concentrates. The writer has suggested in another paper—"Notes on the Metallurgy of Wulfenite," published in *Chemical and Metallurgical Engineering*, vol. xxi, Sept. 15, 1919, p. 364—a process for such treatment.

In general, it may be stated that deposits of wulfenite are confined almost wholly to veins in which it occurs with other lead minerals, but sometimes occurring in seams, stringers and cracks throughout ore bodies that are mined for gold and silver.

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[5] Bonardi, J. P., and Barrett, E. P., Tech. Paper 231, Bureau of Mines, "Determination of Molybdenum."

[6] *Loc. cit.*, p. 45.

[7] Horton, *loc. cit.*, pp. 45–53.

CONCENTRATION AND ASSOCIATED MINERALS.

The successful concentration of wulfenite presents few difficulties, as the ordinary wet processes of concentration by jigs, tables and vanners, such as are used in concentrating mills for treating lead, copper, zinc and pyrite ores, may be applied with success on wulfenite ores. These ores are also amenable to pneumatic separators of various types, which can be used when it is difficult to obtain a water supply for the wet processes. Wulfenite rarely occurs in finely disseminated form, as is common with certain tungsten ores. A small amount of crushing will give a free cleavage of the mineral from the associated gangue; therefore, the conditions for wet concentration, or pneumatic methods, are favorable. In addition, wulfenite does not slime to the same extent as some of the more common minerals, such as galena and pyrite. The specific gravity is high, 6.7 to 7, so that it can readily be separated from the accompanying gangue matter, excepting the heavy minerals and barite.

Vanadinite and several of the lead minerals—cerrusite, anglesite, galena, pyromorphite and mimetite—which often occur with wulfenite, are also recovered in the wulfenite concentrates, as they have nearly the same specific gravity. Usually a concentrate of 15 to 20 per cent. MoO_3 is the best obtainable when the above mentioned lead minerals occur to any extent in the ore. Pure wulfenite contains 39.23 per cent. MoO_3 and 60.77 per cent. PbO. Wulfenite buyers sometimes specify that the concentrate should contain a minimum of 20 per cent. MoO_3, or 13.33 per cent. Mo. Though the presence of other lead minerals lowers the grade of concentrate, any metallurgical process recovering the molybdenum in the slag should also recover the lead as bullion, along with any accompanying gold or silver. The ores of the Mammoth mine, about 3 miles from Mammoth at Shultz, Pinal County, Arizona, were worked originally for their free gold content alone, which was said to be $6 to $7 per ton. Part of the tailings from these workings later supplied 750 tons of wulfenite concentrates out of 795 tons of combined wulfenite and molybdenite concentrates that constituted the total production of this county in 1903.[8]

[8] Pratt, J. H., "The Steel-Hardening Metals." Mineral Resources, U. S., for 1903, U. S. Geol. Survey, 1904, p. 308.

A flow sheet and description of the wet process employed in a wulfenite concentrating mill at Mammoth, Pinal County, Arizona, which treated the ore from the Mammoth mine at Shultz, is given by Horton.[9] This mill treated dump tails in which the ore had been originally crushed in a stamp mill and passed over amalgamation plates; later the tailing from this process was cyanided to recover the free gold lost in the first operation. After these two treatments were given the ore, although it was so fine that over 75 per cent. passed a 200-mesh, it was treated for wulfenite, which amounted to about 1 per cent., or equivalent to about .4 per cent. MoO_3. It was these tailings that supplied in 1903 750 tons of wulfenite concentrates out of the 795 tons of combined wulfenite and molybdenite concentrates previously mentioned. In 1915 it was estimated that these Mammoth tailings contained 200,000 to 250,000 tons of material of 1 to 2 per cent. wulfenite. Despite the low grade and the fineness, a recovery of about 70 per cent. was made in a concentrate averaging about 23 per cent. MoO_3 and 61 per cent. PbO. This was obtained after screening through 4-mesh, followed by simple classification by five "hindered settling" classifiers and one settling cone placed in series. The spigot product from these classifiers was sent to sand tables of the Overstrom, Ludwig, Card and Wilfley types. It was recommended to the company treating this material at that time (June, 1915) that the extraction of wulfenite could be considerably improved by the treatment of the fines on slime tables or slime vanners. The mill has been closed down for some time, since most of the molybdenum during the war was supplied from the sulphide ore (MoS_2). Whatever new changes had been made in the flow sheet up to the time of closing down, could not be ascertained, as the operators after closing the mill had moved out of the territory.

In order to show the wide range of processes that may be successfully applied to wulfenite ores in general, concentration experiments were carried out at this station by Horton [10] which resulted in high extractions. Horton concludes that wulfenite ores in general could be treated efficiently by wet concentration, approximately as follows:

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[9] *Loc. cit.*, Bull. 111, Bureau of Mines, p. 177; *Min. and Sci. Press*, vol. cxiv, 1917, No. 8.

[10] *Loc. cit.*, p. 110–120.

After the ore has been crushed in a jaw or gyratory crusher to about one-half inch size, it should be further crushed in rolls to about one-quarter inch, and the product screened into three series of sizes. Approximately these sizes should be as follows: Through a 4-mesh and on 8-mesh, and through 8-mesh and on 12-mesh; these two sizes to be treated on jigs: through 12-mesh and on 20-mesh, through 20-mesh and on 40-mesh, through 40-mesh and on 80-mesh, and through 80-mesh and on 120-mesh; these four sizes to be treated on concentrating tables, and the material through 120-mesh to be treated on slime tables. The jigs should be operated so as to obtain as clean concentrates and tailings as possible, and the middlings, after recrushing (perhaps through 20-mesh), should be appropriately sized for reconcentration by the tables.

The above statement indicates the amenability of the ordinary type of wulfenite ores to ore dressing methods. Horton states, "the costs of concentrating wulfenite ores by wet processes are, in general, comparable to those of treating ores of galena, sphalerite, chalcopyrite, etc., by similar methods."

SEPARATION OF WULFENITE FROM BARITE.

Wulfenite has been found occurring with barite, and it is only when associated with gangue of such high specific gravity that the problem of separation and satisfactory recovery of the wulfenite becomes difficult, and the methods adopted for ore dressing should be carefully worked out. This problem will be taken up in detail in this paper. Since barite is the highest specific gravity gangue mineral that is found associated with wulfenite, it was deemed advisable to find out whether any special treatment would be necessary in its concentration. The ore from the Mammoth dump, cited above, did not contain any barite, so its separation from wulfenite did not enter into consideration. Horton cites no case where barite gangue was found occurring with wulfenite in any appreciable quantity.

A sample of wulfenite concentrate, whose principal gangue mineral consisted of barite, was kindly furnished to the Rocky Mountain Station by a copper company operating in Arizona. The company is developing a wulfenite mine containing considerable barite gangue matter associated with rhyolite, quartz, several lead minerals, such as mimetite, pyromorphite, vanadinite, cerrusite and anglesite, and a small amount of copper, principally in the

[11] The separation of vanadinite from wulfenite has long been considered a difficult problem; it is the writer's intention to carry on in the future an investigation of this problem.

form of chrysocolla. The milled ore assayed approximately 2 per cent. molybdenum; the mined ore is of a lower grade and must be sorted before sending to the mill.

BARITE "MIDDLING" MATERIAL.

The disposal or treatment of the middling material that was formed at the concentrating mill was held up pending the results of future ore dressing experiments. This middling material contained 52.20 per cent. barite ($BaSO_4$) and 5.50 per cent. molybdenum in the form of wulfenite. This product represented the barite concentrates or middling material taken from a Wilfley table in treating the original ore. In working on the original ore at the mill, it was found that passing the material once over a Wilfley table made a fairly clean concentrate and approximately a 60 per cent. extraction, if a great amount of this middling material containing the barite was rejected. This result was obtained on treating mined ore that had received no special treatment as to classification except grinding and a simple screening through approximately 10-mesh. Such a feed, when passed over a Frue vanner, gave a 63 per cent. extraction and a concentrate ranging from 15 to 17 per cent. molybdenum. In this connection, it can be stated that the adaptability of vanners to the treatment of wulfenite ores has been only recently noticed to any extent. In treating this particular ore, the vanner proved an excellent machine to remove the copper mineral from the wulfenite. Although it was known that wulfenite is somewhat friable, it was found that the very fine wulfenite minerals of an unclassified feed would, when submitted to a vanner, readily attach themselves to the moving surface and be retained. This is because the mineral is readily wetted; while the gangue particles, being of lower specific gravity and not so easily wetted, would be carried off by the stream of water, even though the larger in size. After obtaining the richer concentrates from the vanner and the Wilfley table, there still remained a middling product composed of grains containing both heavy and light minerals. It is this class of material which will be considered in this paper. It is composed chiefly of barite, quartz, wulfenite and several of the lead minerals already described. The wulfenite was present in particles ranging in size from minute specks to pieces retained by a 12-mesh screen.

PROCEDURE OF TESTS.

In testing an ore for ore-dressing possibilities, there is probably nothing so enlightening as screen classification, assay of products and experimentation upon them by different metallurgical processes. The use of the microscope in this connection also can not be over-emphasized.[12]

Accordingly, the so-called middling material, as received, was first screened into six products as follows:

Screen Analysis (Feed Assayed 5.50 Per cent. Mo.).

	Per cent. Wt.	Per cent. Mo.	Content Mo.
−10 +20	13.74	2.50	.344
−20 +28	14.40	3.00	.432
−28 +35	15.65	3.20	.473
−35 +48	17.35	9.67	1.678
−48 +65	22.50	7.40	1.665
−65	16.36	5.42	.887
	100.00	5.50	5.48 grams.

These screened products were examined separately under the microscope to ascertain the degree of locked wulfenite grains in order to determine whether the material would be classed as a true middling and would need any further crushing to liberate the wulfenite before submitting to further concentration. The treatment of middlings has followed, as a rule, two well-beaten paths: reground and returned to ore stream; or returned to ore stream without regrinding. This results often in mixing two products of widely different grades; the ore itself being perhaps of low content and the middlings of relatively high content, as regards the mineral to be saved. This fact must be borne in mind in studying the treatment to be given the material under discussion. On examination under the microscope, the plus 20-mesh was found to be the only screen product containing any locked material, and this was only small in amount. That the material as received was not a true middling was readily seen, as the term "middling" is applied to a crushed product, the individual grains

[12] The use of the microscope for use in connection with an ore dressing problem is described in another paper, "Approximate Quantitative Microscopy of Pulverized Ores," by W. H. Coghill and J. P. Bonardi, Tech. Paper 211, Bureau of Mines.

of which are composite; that is, they contain, attached to or imbedded in the gangue, particles of valuable mineral. Theoretically, no free grains of valuable minerals should be present, but in practice there will always be a varying proportion of such grains. The proportion of locked grains in this so-called middling material, being of such small proportion to the free grains, would readily classify it as not a true middling.

Next, in order to try out the separation of the wulfenite from the barite in the various screen products, as shown by the screen analyses, as well as on the unclassified material as received, the different sized products and unclassified material were submitted separately to a laboratory experimental size Wilfley table. Since the screen products were dry-sized between small limits, the separation of the free mineral grains of wulfenite from the gangue barite, in which the difference of specific gravity exceeds two units, should be an easy matter. The results of a few simple tests made on the small experimental size Wilfley table are as follows. The material in each run was passed but *once* over the table, and only the concentrates of each were collected, weighed and assayed.

TABLE I.

Concentration Tests on Small Experimental Size Wilfley Table.

Run	Mesh	Wt. taken	Per cent. Mo.	Wt. of Conc.	Per cent. Mo. in Con.	Per cent. Recovery Mo.	Remarks
1	Unclassified material	500 g.	5.50	28 g.	14.17	14.45	
2	−10 +20*	500 g.	2.50	none	....	....	No separation
3	−20 +28*	500 g.	3.00	none	....	....	No separation
4	−28 +35*	500 g.	3.20	50 g.	9.40	28.80	Poor separation
5	−35 +48	450 g.	9.67	205 g.	12.12	57.05	
6	−48 +65	450 g.	7.40	155 g.	13.16	61.20	
7	−65	500 g.	5.42	160 g.	12.60	74.50	

* The wulfenite crystals of these meshes, being large, thin tabular and flaky, rolled along over the table with the barite gangue, and no line of demarcation could be made between the minerals of different specific gravity.

Jigging of these sizes was not attempted, since the company submitting the wulfenite ore had not installed any jigs in the mill. Further, expert attention would, in all probability, be required in the successful operation of jigs treating material of such fineness; besides taking into consideration wulfenite which when occurring in an ore in square, tabular, and sometimes ex-

tremely thin crystals would cause trouble by not following the settling ratio of the specific gravity difference.

In the runs made, as indicated in Table I, the grade of concentrates in each case could have been bettered by cutting off a larger middling product or by running the concentrates that were collected over the table a second time. This was not deemed necessary when using the experimental machine, since only indicative results were desired.

Table I clearly illustrates the fact that the large wulfenite crystals—greater than 35-mesh—in association with barite are not adapted to table work, since they have a tendency to roll along with the coarse barite gangue. Wulfenite grains or crystals in this case, being approximately the same weight, due to their thin and tabular structure, as barite grains, did not have an opportunity to arrange themselves on the table according to their specific gravity differences.

In order to make a comparison of the sized runs with an unclassified ground feed, a sample of the original material was ground dry in a ball mill to pass 80-mesh; 2000 grams of this minus 80-mesh material was run over the experimental table *once,* as in runs made with screened sizes. The following table represents the results obtained:

TABLE II.

Run Made on Minus 80-Mesh Material on Wulfenite Barite Ore, Passed Once Over Table.

Sample	Wt. in grams	Per cent. Mo.	Per cent. $BaSO_4$	Per cent. recovery Mo.	Per cent. recovery $BaSO_4$
Head.....	2000	5.50	52.20		
Conc.....	508	14.32	21.14	66.20	10.28
Mid.....	338	5.76	51.10	17.72	53.01
Tails.....	726	1.86	76.20	12.28	16.55
Loss.....	428	.97*	49.20*	3.80	20.16
Footing.....	2000			100.00	100.00

* Calculated.

Table II clearly illustrates the following points:

1. That crushing in this manner does not entail any great loss of wulfenite in the slime going to waste, since only 3.80 per cent. Mo was unaccounted for.

2. That 66.20 per cent. of the wulfenite can be recovered in a concentrate of marketable grade.

3. That barite can be successfully concentrated from wulfenite, since only 10.28 per cent. of the total remained with the concentrate.

4. That the above tails and middling product, respectively, are of the same grade as the original milled ore and first middling produced and, consequently, further recovery can be made by treatment.

The results of the experiments as performed and given in Tables I and II clearly illustrate the fact that in the wet separation of wulfenite from barite, when using tables, particular attention must be given to the ore-dressing method adopted, and to the degree of grinding. Grinding at least through 48-mesh would be recommended for this class of material, as Table I indicates.

In order to determine approximately the highest grade of concentrate that can be produced from this barite middling material, 500 grams of the concentrates, assaying 14.32 per cent. molybdenum produced in experiment as given in Table II, were carefully re-run several times over the Wilfley table with the following results. No slime was produced in this treatment, so the products were easily collected and recovered.

TABLE III.

Concentration Test for High-Grade Product.

Sample	Wt. in grams	Per cent. Mo.	Per cent. recovery Mo.
Head	500	14.32	
Conc.	268	17.85	67.00
Tails	230	9.96	32.00
Loss	2		1.00
	500		100.00

The above content of 17.85 per cent. molybdenum in the concentrate represents 26.77 per cent. MoO_3. Theoretically a concentrate consisting entirely of pure wulfenite contains 39.23 per cent. MoO_3, so the above concentrate represents a grade of 68 per cent. pure wulfenite. This would then, in all probability, represent the highest grade of concentrate that could be obtained by treating such an unclassified feed of this material. The following chemical analysis of this concentrate will further emphasize this point:

ANALYSIS OF CONCENTRATE.

	Per Cent.
MoO_3	26.93
PbO	52.15
Fe_2O_3	1.03
Al_2O_3	1.19
SiO_2	3.30
V_2O_5	.65
P_2O_5	.17
As_2O_5	.90
$BaSO_4$	12.76
Cu	none
Total determined	99.08

The above analysis indicates that theoretically further concentration could be performed by elimination of the 12.76 per cent. barite and the little other gangue still remaining with the concentrate; but in practice, if this were attempted, close sizing of the feed would be required. Other lead minerals than wulfenite, vanadinite, mimetite, pyromorphite, are indicated by the excess amount of lead oxide that is required to combine with the above elements given in the analysis. The presence of both anglesite and cerrusite in the concentrate was later confirmed, but only in traces.

FLOTATION TESTS ON BARITE "MIDDLING" MATERIAL.

On this particular ore, ground through 80-mesh, flotation was attempted after giving it a sulphidizing treatment. The material was easily sulphidized by heating for a short period within a dilute sodium sulphide solution, in proportion of 10 pounds Na_2S to 1 ton of ore with a pulp ratio of 1 : 1. In treating the sulphidized material in a flotation machine, it was found on several trials with various oil mixtures and variations of factors, that the barite and wulfenite would come over with the froth in approximately the same proportion as contained in the feed. In tracing down this cause, it was found that this was due to the fact that part of the barite and the siliceous gangue matter was iron stained; and as this iron-stained material was easily sulphidized, it was carried along over with the sulphidized wulfenite, and consequently no marked separation could be made. Also it was found in performing the sulphidizing treatment that a con-

siderable amount of wulfenite was rendered soluble and, consequently, could not be accounted for in assaying the products. The results did not warrant doing any further work by flotation; therefore, this was discontinued.

CONCLUSIONS AS TO LABORATORY TESTS.

As the experimental tests were of necessity made on a laboratory scale and on very small samples of ore, the results obtained on this particular ore must be considered only as indicative of what might be expected from the treatment of commercial quantities of ore on machines of standard size, where the proper conditions for separation can be better controlled. The results from the small laboratory machine are at the best only indicative and should be regarded only in this light. Flotation was not a factor on the ore treated.

The results found with the experimental Wilfley table indicate that wulfenite can be concentrated from a barite gangue with very promising results, since on the small laboratory machine used, a recovery of between 60 and 70 per cent. of the molybdenum could be effected by passing the material only *once* over the table. It must be remembered also that a recovery had previously been made on the original milled ore of over 60 per cent., so that the additional increase obtained from the middling material, when ground through 80-mesh and with no further classification, gives a total recovery of over 85 per cent. This recovery on material that had received no special classification, outside of grinding, emphasizes further the adaptability of wet concentration methods to wulfenite ores, even with such high specific gravity gangue as barite. By a slight rearrangement of the mill circuit, wulfenite should be as readily separated from barite as from gangues of a lower specific gravity.

In conclusion, the author wishes to express his appreciation and gratitude to Dr. R. B. Moore, Superintendent of the U. S. Bureau of Mines mining experiment station at Golden, Colorado, for his valuable suggestions throughout the progress of the work.

GOLDEN, COLORADO,
U. S. BUREAU OF MINES.
September 24, 1919.

Vagrant Mines in the Atlantic Ocean.—It is well known that the belligerents, especially the English, Americans and Germans, sowed the sea with thousands of contact mines, and that many of these have drifted from their anchorage. The principal fields were the more important harbors, the British channel and the northern boundary of the North Sea. The last named mine-field was of enormous extent and density. As vagrant mines are a very serious menace to shipping, the question as to their probable course from their moorings is of great importance. It has been studied by the well-known oceanographer, the Prince of Monaco, who has for many years been investigating the direction of ocean currents. In the latter part of 1918 he presented a communication to the French Academy of Sciences (*C.V.*, v. 167, 1918, 1049) in which he exhibited a map of the principal currents in the Atlantic Ocean, and pointed out that the principal drift of the mines would be to the nearly circular sweep of waters lying between N. lat. 30° and 45°, and W. lon. 25° and 50°, being just west of Gibraltar. In September of this year he presented another communication (*C.V.*, v. 169, 1919, 562) in which he records the finding of twenty-three mines within the above indicated area, and three others in the neighborhood of the opening of the British channel. The dates of the finds ranged from November 7, 1918, to June 15, 1919. He states, as the result of his studies of ocean currents, that ships sailing between the United States and Europe will find their greatest security in a line running directly north from the mouth of the British channel to 50° N. lat. and following this to 30° W. lon., inclining towards the Newfoundland banks. The Gulf Stream marks the northern limit of danger. The ships which travel between the United States and southern Europe will find their greatest perils in the immediate neighborhood of the European coasts and in the several archipelagoes, south as far as the Canaries, and their greatest security on a line passing a little north of Madeira and tangent to the southern limit of the Saragossa Sea. H. L.

A New Drying Oil. (*Paint Mfrs. Assn. Circ.* No. 75.)—The oil of the seeds of the *Aleurites trisperma*, or soft Lumbang, a species of "candle-nut" tree, of the tropical habitat and rather limited range seems to have excellent drying properties, analogous to those of tung oil. This tree and the true "lumbang" (*A. moluccana*) grow in the Philippines, but it is stated that "soft" variety fruits in Porto Rico grow very well, and hence substantial quantities of the oil might be obtained for use in the United States. The analysis in the laboratory of the Paint Manufacturers' Association found that the Hanus method for iodine number gave very unsatisfactory results with the new oil as it does with tung oil, while the Hubl gave results comparable with those on tung oil. H. L.

FACTORS OF CLIMATIC CONTROL.*

BY

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Table IV, extended, as well as the scanty early data, mainly from the given stations, will permit, back to 1872, is graphically represented by the continuous, light curve at the bottom of Fig. 4. In 1880 and again in 1901 the curve probably does not very closely represent world-wide temperature departures, being, presumably, at both places quite too low, owing, in each case, to an abnormally cold single month in America.

TABLE IV.

Weighted Departures of Mean Temperatures from Normal Temperatures.

WORLD.

Date.	Actual.	Smoothed.	Date.	Actual.	Smoothed.
1872	−0.78	−0.30	1893	−0.34	−0.06
1873	−0.65	−0.47	1894	+0.34	+0.03
1874	+0.20	−0.34	1895	−0.21	+0.10
1875	−1.12	−0.61	1896	+0.49	+0.28
1876	−0.40	−0.60	1897	+0.34	+0.45
1877	−0.48	−0.32	1898	+0.61	+0.46
1878	+0.07	0.00	1899	+0.27	+0.59
1879	+0.33	+0.04	1900	+1.19	+0.76
1880	−0.50	−0.13	1901	+0.40	+0.55
1881	+0.14	−0.02	1902	+0.20	+0.13
1882	+0.14	−0.16	1903	−0.30	+0.10
1883	−1.04	−0.68	1904	+0.81	+0.20
1884	−0.79	−0.61	1905	−0.51	+0.01
1885	+0.17	−0.09	1906	+0.23	+0.05
1886	+0.11	+0.03	1907	+0.23	+0.30
1887	−0.29	−0.05	1908	+0.51	+0.21
1888	+0.26	+0.24	1909	−0.43	+0.11
1889	+0.74	+0.57	1910	+0.69	+0.30
1890	+0.54	+0.40	1911	+0.23	+0.09
1891	−0.21	+0.06	1912	−0.80	−0.40
1892	+0.10	−0.09			

The dotted curve from 1907 to 1911 gives the average temperature departures for the American stations only, and presumably represents world temperature departures much more closely than does the continuous light line for the same time. This is because of two or three exceptionally cold summer months in Europe.

* Concluded from p. 810, Vol. 188, December, 1919.

The dotted curve from 1872 to 1900 gives the smoothed averages of the annual temperature departures from the normal temperatures of the following stations as computed from the actual departures given by Nordmann[31]; Sierra Leone, Recife (or Pernambuco), Port au Prince, Trinité, Jamaica, Habana, Manila, Hong Kong, Zikawei, Batavia, Bombay, Island of Rodriguez, Island of Mauritius.

All these, or practically all, are low-level stations, and most of them either tropical or semi-tropical, and, therefore, should show in general, from altitude influence alone, a smaller, and from latitude influence alone, a greater, abnormality than do the stations whose temperature departures are given by the continuous fine-line curve. Hence, all things considered, the average temperature departures as calculated from the two sets of stations agree remarkably well, so that one can say with, presumably, a fair degree of confidence, that the heavy curve, *T*, approximately represents the average of the departures of the mean annual temperatures from the normal annual temperatures of equatorial and high altitude regions of the earth, or that *T*, with the above restrictions, is the curve of world temperatures.

Much additional statistical evidence bearing on this point and supporting the conclusion just given, has been published by Mielke.[32] This consists of the average annual temperatures from 1870 to 1910 of 487 widely distributed stations, with, however, numerous and extensive breaks—in fact, the records of only a few stations cover the entire period. By grouping these stations according to zones, tropical, subtropical, warm temperate, cold temperate and frigid, and then averaging and smoothing the zonal annual temperature departures, giving all equal weight, values were found which run substantially parallel to those already found but of less (about half) amplitude, quite as anticipated from the fact that stations above the dust, fogs and many clouds of the lower atmosphere must be more sensitive to variations in the transparency of the outer atmosphere and to solar changes than are those (the great majority) located at, or not more than a few hundred metres above, sea level. Either curve might, therefore, be used in a discussion of the causes and periods of temperature

[31] *Revue Générale des Sciences*, August, 1903, pp. 803–808. Annual Report, Smithsonian Institution, 1903, pp. 139–149.

[32] *Aus dem Archiv der Deutschen Seewarte*, 36, Nov. 3, 1913.

changes, but in what follows the curve of larger amplitudes or the curve of high altitude stations will be used because: (*a*) data for it but not for the other are available through the period of the Katmai veil of dust, (*b*) it is freer from surface disturbances and therefore more representative of solar and high atmospheric conditions, (*c*) high altitude temperatures are more effective than those of sea level in modifying glacial conditions.

Relation of World Temperatures to Pyrheliometric Values.—Curve *P*, also of Fig. 4, gives the smoothed course of the annual average pyrheliometric readings, as computed from the actual values given in Fig. 1. The insolation intensity data, covering the whole of the depression that had its minimum in 1885, were obtained at a single place, Montpellier, France, by a single observer, L. J. Eon,[33] who confined himself to noon observations with a Crova actinometer. It may be, therefore, that merely local and temporary disturbances produced a local insolation curve that was not quite parallel to the curve for the entire world. At any rate, the drop in the solar radiation values obviously was due to dust put into the atmosphere by the explosion of Krakatoa in August, 1883, and it would seem that the effects of this dust both on the surface temperatures and on pyrheliometric values must have been greater during the latter part of 1883 and in 1884 than they were in 1885, when much of the dust certainly had already settled out of the atmosphere, and this supposition is well supported by the pyrheliometric and temperature drops that immediately followed the volcanic explosions of 1903 and 1912, and their partial recovery within a single year. Nevertheless, the pyrheliometric values must be accepted as obtained. Indeed, this exceptional lag is not quite unprecedented, since the coldest year following the similar, though more violent, explosion of Asamayama, just one hundred years earlier, was not the year of the explosion, 1783, nor the following year, but 1785.

It is probable that in the earlier, as certainly in the later, of these unusual cases the dust was thrown to such great altitudes that the finer portions were nearly, or quite, two years in reaching the lower level of the isothermal region. Clearly, too, much of this dust, while perfectly dry, probably was so fine as merely to scatter even solar radiation, and yet on reaching the more humid portions of the atmosphere the particles may have gathered suf-

[33] *Bulletin météorologique du Département de l'Hérault*, 1900.

ficient moisture to assume reflecting size, and, therefore, seriously to interfere with insolation. This is merely suggested, but in no wise insisted upon, as a possible explanation of the unusual pyrheliometric lag after the explosion of Krakatoa.

It is obvious, from a mere glance, that the pyrheliometric and the temperature curves, or curves P and T, have much in common. This is especially marked by the large and practically simultaneous drops in the two curves in 1912, following the eruption of Katmai. But while a relation between these curves thus appears certain, the agreement is so far from perfect as to force the conclusion that pyrheliometric values constitute only one factor in the determination of average world temperatures.

Sun-spots and Temperature.—It has been known for a long time that the curve of sun-spot numbers, curve S, Fig. 4, and the curve of earth temperatures, curve T, follow or parallel each other in a general way, in the sense that the fewer the spots the higher the temperature, with, however, puzzling discrepancies here and there. Both these facts, the general agreement between the phenomena in question and also their specific discrepancies, are well shown by the curves S and T of Fig. 4, and, while the discrepancies are marked, it is obvious that, on the whole, the agreement is quite too close to leave any doubt of the reality of some sort of connection between sun-spots and atmospheric temperatures. Just how or by what process this relation conceivably may exist will be discussed below.

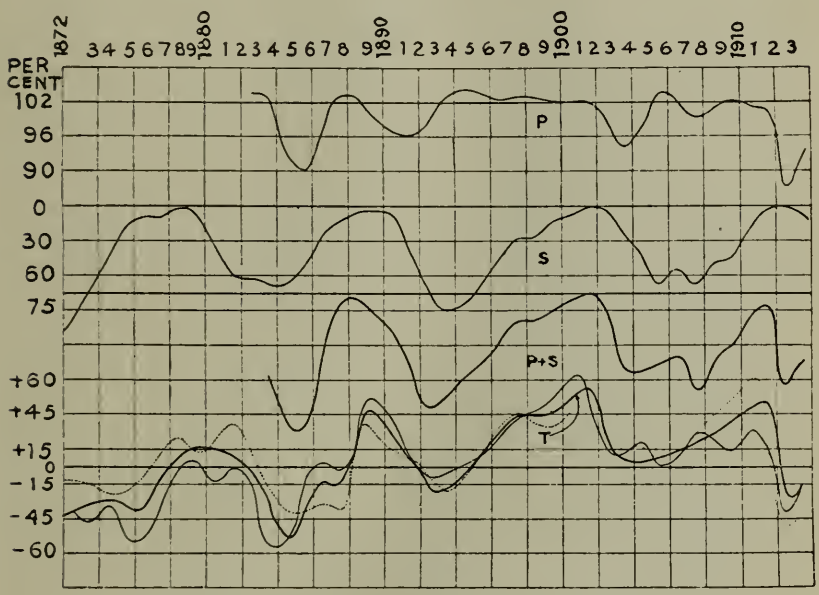
Combined Effect of Insolation Intensity and Sun-spot Influence on Atmospheric Temperatures.—Since it is obvious that the insolation intensity and the number of sun-spots each exerts an influence on the temperature of the earth, it is clear that some sort of a combination of the two curves P and S should more closely parallel the temperature curve, T, than does either alone. It is probable that the sun-spot effect is not directly proportional to the actual number of spots, but, however this may be, the direct combination of the curves P and S gives the resultant $P+S$, which, as a glance at the figure shows, actually parallels the curve of temperatures, T, with remarkable fidelity. Exactly this same combination, from 1880 to 1909, has been made by Abbot and Fowle,[34] whose lead in this important particular is here being

[34] *Smithsonian Miscellaneous Collections*, vol. lx, No. 29, 1913.

followed, and the resultant curve found to run closely parallel to the curve of "smoothed annual mean departures" of the maximum temperatures of fifteen stations in the United States.

Probably the most striking point of agreement, one that must strongly be insisted upon, as shown by Fig. 4, between the combination curve and the temperature, occurs in 1912, when, in spite of the fact that the sun-spots were at a minimum, indicating that, according to rule, the temperature should be high, the temperature curve dropped greatly and abruptly; obviously, because of the

FIG. 4.



Smoothed pyrheliometric, sun-spot, and temperature curves.

simultaneous and corresponding decrease in the intensity of solar radiation produced by the extensive veil of Katmai's dust, precisely as happened at spot minima after the explosion of Asama in 1783. Both cases, since they occurred during spot minima, show distinctly the great influence volcanic dust has on terrestrial temperatures.

Temperature Variations Since 1750 as Influenced by Sun-spots and Volcanic Eruptions.—Sun-spot numbers [35] month by month

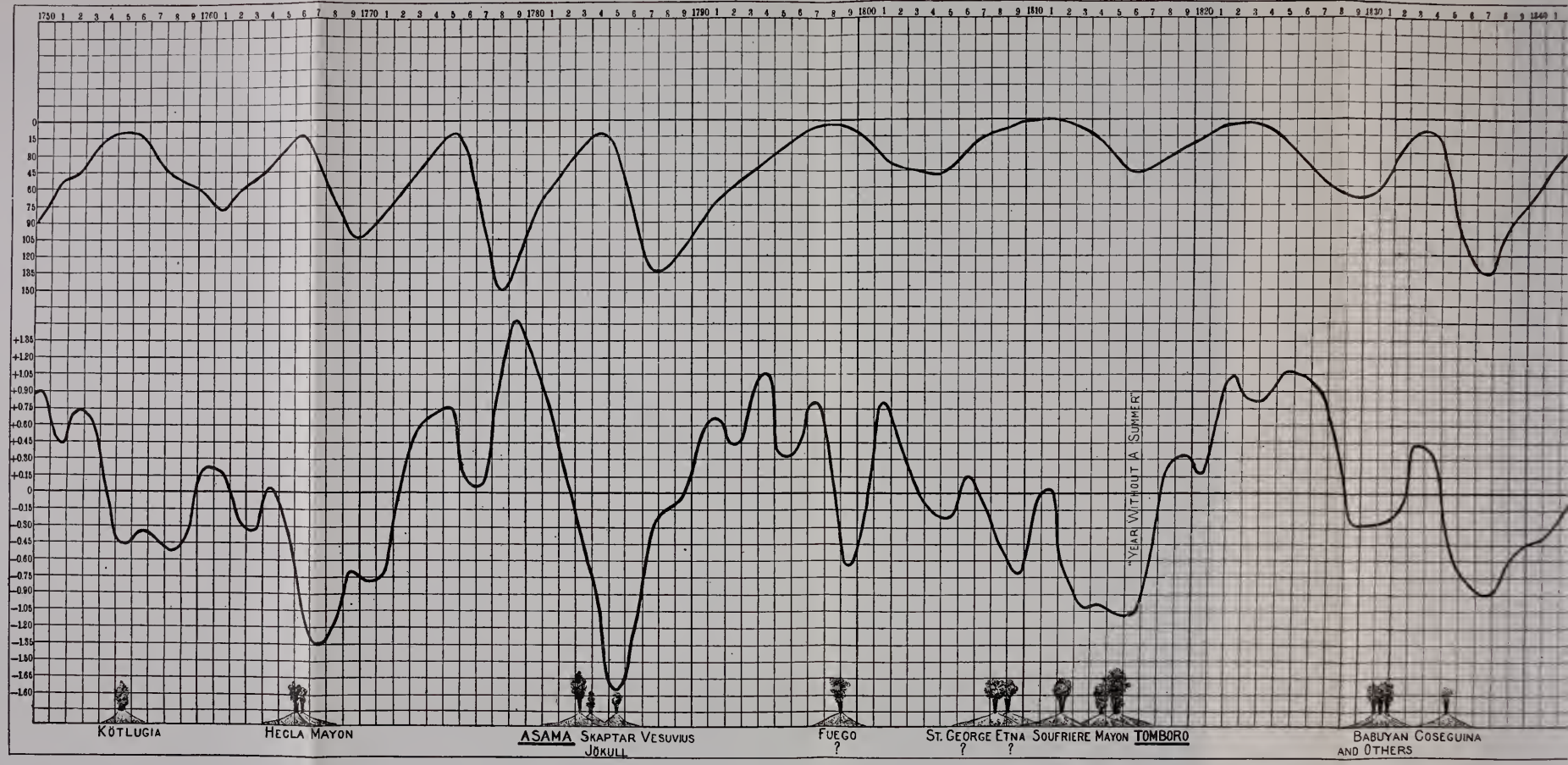
[35] Wolfer, *Astronomische Mitteilungen*, 93, 1902, and later numbers.

are fairly well known since July, 1749, and so, too, are the annual temperature variations[36] from about the same time, and, therefore, the data at hand for comparing these two phenomena over a continuous period of a little more than 164 years, or from at least the beginning of the year 1750 to the present date. Fig 5 makes this comparison easy. The bottom curves give the smoothed annual temperature departures, as computed from Köppen's actual annual departures, using all stations, while the top curve follows Wolfer's annual average sun-spot numbers. Of course, the earlier observations, both of sun-spots and of temperatures, were few in number and more or less unsatisfactory in comparison with those obtained during the past thirty, or even forty, years. Nevertheless, it is clear from Fig. 5 that at least since 1750, the date of our earliest records, and presumably, therefore, since an indefinitely distant time in the past, the two phenomena, atmospheric temperature and sun-spot numbers, have in general varied together, with, however, marked discrepancies from time to time. These we shall now consider, and shall show that they occurred, in every important case, immediately after violent volcanic eruptions.

Volcanic Disturbances of Atmospheric Temperature Since 1750.—It must be distinctly remembered that the earlier temperature records, because of their limited number, if for no other reason, give only the general trend of world temperatures. Again, the record back to 1750 of even violent volcanic eruptions is necessarily incomplete; and, besides, *not all great eruptions decrease the surface temperature—only those that drive a lot of dust into the isothermal region, or very high atmosphere*, and even then decrease it perceptibly in only those regions, usually extensive and at times world-wide, over which the dust spreads. Pronounced and long-continued sky phenomena, therefore, of the type that followed the eruption of Krakatoa, furnish the best evidence of volcanic violence in the sense here used. Finally, there can be no particular test save where the temperature is low in comparison with that which the number of sun-spots would indicate. Obviously, then, no matter how close the actual relation between the phenomena may be, the errors and the incom-

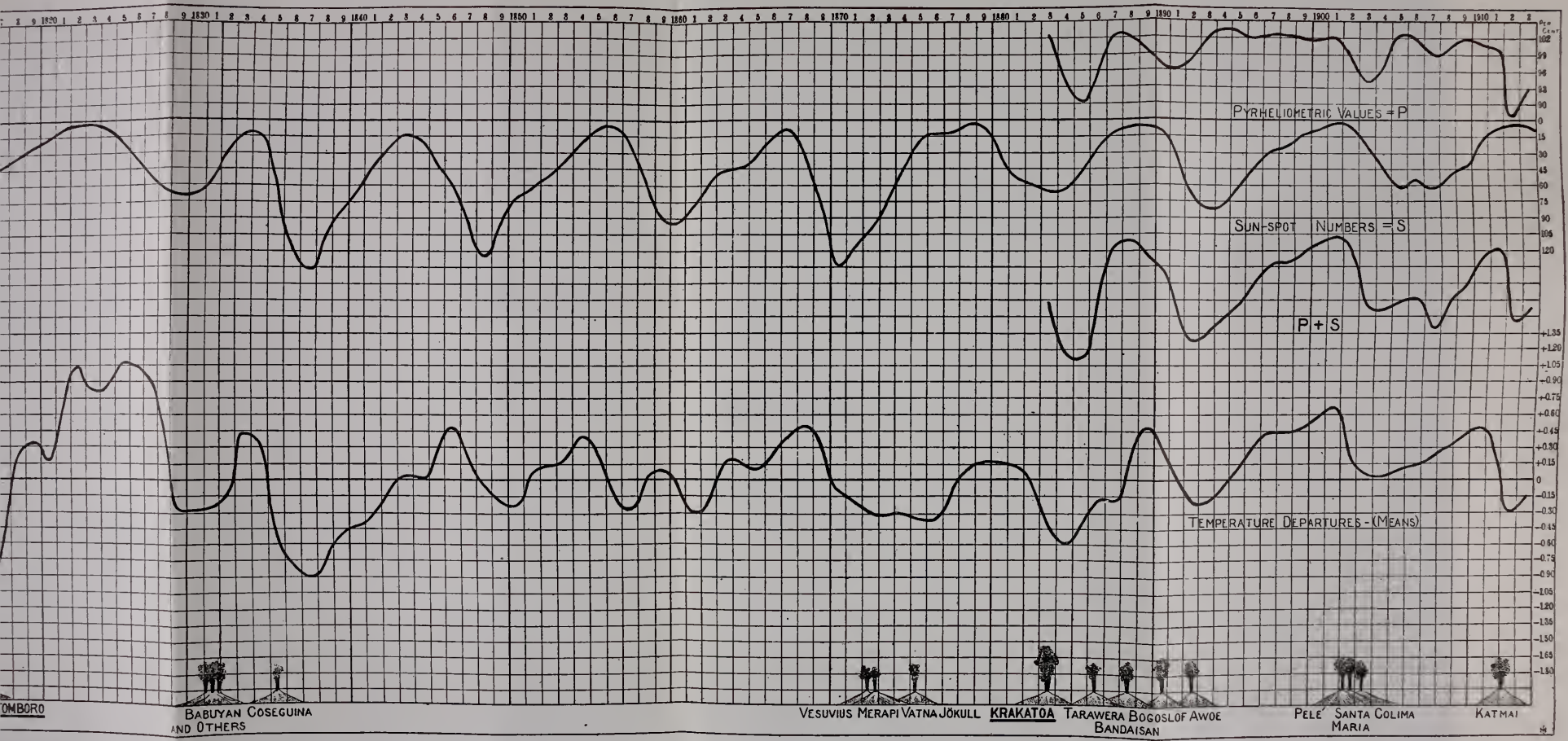
[36] Köppen, *Zeit. Oesterreich. Gesell. für Meteorologie*, vol. viii, pp. 241 and 257, 1873.

Fig. 5.



Relations of pyrheliometric values and mean temperature departures to sun-spot numbers and vole

Fig. 5.



ns of pyrheliometric values and mean temperature departures to sun-spot numbers and violent volcanic eruptions.

pleteness of the recorded data would prevent the discovery of more than a general relation.

Of course, it will naturally occur to one to ask about special cases, such as the cold years of 1783–4–5, and, in particular, 1816, the famous "year without a summer," "poverty year," or "eighteen hundred and froze-to-death." The first of these, 1783–5, followed, as already explained, the great explosion of Asama in 1783, while the second, the "year without a summer," that was cold the world over, followed the eruption of Tomboro,

Temperature and Sun-spot Discrepancies.

Date.	Nature of discrepancy.	Probable cause.
1755–6	Cold	Kötlugia, Iceland, 1755, Oct. 17.
1766–7	Cold	Hecla, Iceland, 1766. Apr. 15 to Sept. 7.
		Mayon, Luzon, 1766.
1778–9	Warm	Maximum number (annual) of sun-spots ever recorded and unusually short spot period. Can it be that the solar constant actually was notably greater than usual at this time?
1784–5–6	Cold	Asama, Japan, 1783, most frightful eruption on record.
		Skaptar Jökull, Iceland, 1783, June 8 and 18.
		Vesuvius, Italy, 1785.
1799	Cold	Fuego (?), Guatemala. (Uncertain.)
1809	Cold	St. George (?), Azores, 1808. (Uncertain.)
		Etna (?), Sicily, 1809. (Uncertain.)
1812–13–14–15–16	Cold	Soufrière, St. Vincent, 1812, Apr. 30.
		Mayon, Luzon, 1814.
		Tomboro, Sumbawa, 1815, Apr. 7 to 12, very great.
1831–2	Cold	Graham's Island, 1831, July 10 to early in Aug.
		Babujan Islands, 1831.
		Pichincha, Ecuador, 1831.
1836–7–8	Cold	Coseguina Nicaragua, 1835, Jan. 20.
		Awatska, Kamchatka, 1837.
1856–7	Cold	Cotopaxi (?), and others, 1855–6. (Uncertain.)
1872–3	Cold	Vesuvius, Italy, 1872, Apr. 23 to May 3.
		Merapi, Java, 1872, April.
1875–6	Cold	Vatna Jökull, Iceland, 1875, March 29 and during April.
1884–5–6	Cold	Krakatoa, Straits of Sunda, 1883, Aug. 27, greatest since 1783.
		Saint Augustin, Alaska, 1883, Oct. 6.
		Tarawera, New Zealand, 1886, June 10.
1890–1–2	Cold	Bogoslof, Aleutian Islands, 1890, Feb.
		Awoe, Great Sangir, 1892, June 7.
1902–3–4	Cold	Pelé, Martinique, 1902, May 8.
		Santa Maria, Guatemala, 1902, Oct. 24.
		Colima, Mexico, 1903, Feb. and Mar.
1912–13	Cold	Katmai, Alaska, 1912, June 6.

[27] Schneider, "Die Vulcanischen Erscheinungen der Erde," p. 1, 1911.

which killed 56,000 people [37] and blew up so much dust that "for three days there was darkness at a distance of 300 miles."[38]

There is a detail in the temperature curve for the years 1886–7 that needs special attention. The temporary depression where, seemingly, the temperature should be steadily rising, obviously was due to the great eruption of Tarawera (June 10, 1886), in New Zealand. This volcano is a little more than 38° south of the equator, and, therefore, furnishes a good example of an eruption on one side of the equator affecting the temperature far to the other side. Doubtless, however, when the dust gets but a little way into the isothermal region the effect is greatest on the volcano's side of the equator.

But if the temperature was decreased by Tarawera, why, one might ask, was not the pyrheliometric curve similarly affected? It was, for several months after the eruption, as the individual monthly values show,[39] but the annual means, plotted in the figure, have the effect of making the pyrheliometric disturbance from Tarawera appear only as a retardation in the recovery from the effects of Krakatoa.

Neglecting the smaller irregularities which may or may not have been of world-wide occurrence, and remembering that, other things being equal, temperature maxima are to be expected at the times of spot minima and temperature minima at the times of spot maxima, the marked discrepancies and their probable explanations may be tabulated as follows:

For the sake of completeness as well as for such little value and interest it may have the following list is added of still earlier great volcanic eruptions and the kinds of seasons that history [40] reports to have followed. Taken by themselves these ancient or preinstrumental records help but little to connect effect with cause. Nevertheless, it is at least pleasing to know that they report precisely those general weather or seasonal conditions which from later and reliable instrumental observations we infer must have happened, provided only that the explosions were sufficiently great.

Confining attention to the first of the above lists, since the value of the second in this connection is doubtful, it will be seen that excepting some ill-defined cases, all of the seeming irregu-

[38] *Rept. Krakatoa Committee Royal Society*, 1888, p. 393.

[39] *Bulletin Météorologique du Département de l'Hérault*, p. 136, 1900.

[40] Henning, *Abhand. des K. Preuss. Meteorol. Inst.*, Bd. II, No. 4, 1904.

Date of eruption.	Volcano.	Type of season, etc.
79, Aug. 24.....	Vesuvius. (Destruction of Pompeii.)	About 80, severe drought for several years in middle Asia. (Accords with low temperature but signifies very little.)
1631, Dec. 16.....	Vesuvius. (Most violent since 79. Height of ash cloud, measured by Braccini, 48 kilometres.)	1632, Apr. 27, destructive snow in Transylvania (Siebenbürgen); May 17, frost in Saxony; hot dry summer in Italy; Oct. 4, very cold in France, 37 soldiers frozen between Montpellier and Baziers. 1633, severe winter; May 22, snow and severe cold in Transylvania.
1636, May 18 to winter	Hecla.....	1637, long, severe winter.
1680.....	Celebes.....	1681, severe drought and cold spring (Evelyn's Diary).
1693, Feb. 13 till Aug.	Hecla.....	1694, hard, snowy winter in both Italy and Spain; May 17, all vineyards of Troyes destroyed by frost.
1694.....	Celebes.....	1695, long, severe and dry winter; cool summer.
1694.....	Amboyna.....	
1694, Nov. 20 till 1695, April.....	Gunong Api.....	
1707, May 20 to Aug.	Vesuvius.....	1708, very mild winter; cold summer; Dec. 10 to 20, very heavy snow in France.
1707.....	Japanese volcano	1709, from Jan. 6, for a month and a half extraordinary severe cold in nearly all Europe; Adriatic Sea and Thames frozen; snow 10 feet deep in Spain and Portugal; 50 days frost in England from Dec. 25, 1708 till March 12, 1709; mild winter in Constantinople, but very severe in eastern North America; May 17, snow in Oedenburg; May 17 and 18, frost in Alsace; cool, rainy summer.
1707, May 25 and July 25	Santorin.....	
1721, May 11 till autumn	Kötlugia.....	1722, cool, wet year.

larities in the temperature curve, and all of the known volcanic eruptions, are satisfactorily accounted for.

It may be concluded, therefore, that the variations in the average temperature of the atmosphere of the kind and magnitude shown by actual records depend jointly upon volcanic eruptions, through the action of dust on radiation, as already explained, and upon sun-spot numbers, through, presumably, some intermediate action they have upon the atmosphere—possibly of the nature explained in the next chapter.

Magnitude and Importance of Actual Temperature Changes.—The actual temperature range from sun-spot maximum to sun-

spot minimum varies, roughly, from 0.5° C. to 1° C., or possibly more, while the effect of volcanic dust appears to be fully as great—on rare occasions even much greater. In some ways, and in respect to many things, a range of average temperatures of even 1° C. is well-nigh negligible, and, therefore, however important the results may seem to the scientist, the ultra-utilitarian would be justified in asking, "What of it?"

Much of it, in a distinctly practical as well as in a purely scientific sense, as is true of every fact of nature. For instance, during the summer, or growing season, a change of 0.5° C. produces a latitude shift of the isotherms by fully 80 miles. Hence, if there is but little or no volcanic dust to interfere, during sun-spot minima cereals and other crops may be successfully grown 50 to 150 miles farther north (or south in the southern hemisphere) than at the times of sun-spot maxima. This alone is of great practical importance, especially to those who live near the thermal limits of crop production.

In addition to changing the area over which crop production is possible, a change of average temperature also affects, in some cases greatly, the time of plant development. Thus Walter [41] has shown that a change of only 0.7° C. may alter, and in Mauritius has been observed actually to alter by as much as an entire year, the time required for the maturing of sugar cane. Hence the temperature changes that normally accompany sun-spot variations, though small in absolute magnitude, are of great importance, and, by availing ourselves of the reasonable foreknowledge we have of these changes, may easily be made of still greater importance.

In forecasting these small but important climatic changes it must be distinctly remembered that to the fairly periodic, and therefore predictable, sun-spot influence must be added the irregular and unpredictable volcanic effects. But even here the case is not bad for the forecaster, because the volcanic dust always produces, qualitatively, the same effect—a cooling—and because both the amount of this cooling and its duration (generally only one or two years, as already explained) may approximately be estimated from the nature of the volcanic explosion itself.

[41] "On the Influence of Forests on Rainfall and the Probable Effect of 'Déboisement' on Agriculture in Mauritius" (1908).

CHAPTER V.

OTHER FACTORS OF CLIMATIC CONTROL.

(9, 10, 11, 12, 13, 14.)

9. SUN-SPOTS.

As already stated, the average temperature of the earth as a whole varies inversely with the frequency of sun-spots.

How Sun-spots May Change Earth Temperatures.—If the solar constant should remain the same from spot maximum to spot minimum it clearly would not be easy to see at a glance why the surface temperature of the earth should vary as it does with spot numbers; and the situation is still more difficult if, as observations appear to indicate, the lowest temperatures occur when the solar constant is greatest and the highest temperatures occur when this constant is least. There is, however, a possible explanation of the paradox, and, while it may not contain the whole truth, it nevertheless is sufficient to show *a priori* that in all probability our temperatures do change from spot maxima to spot minima without a corresponding change in the solar constant, and also to show that a decrease in our surface temperatures may accompany even a slight increase in the solar constant.

The explanation in question has already been given elsewhere,[42] and the original paper must be consulted by those who wish to weigh all the details of the argument. Briefly, however, the argument is as follows:

1. At the times of spot maxima the solar corona is much more extensive than it is at the times of spot minima—a well-known observation.

2. This corona consists, in part at least, of reflecting particles, as many eclipse observations have shown, and so may be regarded as dust in the solar atmosphere.

3. The brightness of the sun, as every solar observer knows, drops off from centre to limb.

4. This drop, as reported by various observers, is greater the shorter the wave-length, and due, almost certainly, to diffuse scattering.

From the observational facts it follows that during spot

[42] Humphreys, *Astrophys. Jr.*, 32, p. 97, 1910.

minima, other things being equal, the solar spectrum must necessarily be richer in violet and ultra-violet radiation than it is during spot maxima.

But, as experiment has shown,[43] ultra-violet radiation of shorter wave-length than λ 1850 is strongly absorbed by oxygen, with the result that some of the oxygen is converted into ozone. Hence, since the atmosphere of the isothermal region is cold and dry (conditions favorable to the stability of ozone) and since of the gases of the upper atmosphere only oxygen is appreciably absorptive of radiations between λ 1250 and λ 1900[44] the stratosphere was believed to contain more or less ozone, a belief now fully confirmed by several observers,[45] and long ago virtually confirmed by Ångström.[46] In so far, then, as this ozone is produced by the action of ultra-violet solar radiation, it is also logical to expect it to be greater in quantity when the short wave-length radiation, to which it is due, is most intense, or, presumably, therefore, at the times of spot minima. Now, according to the experiments of Ladenburg and Lehmann,[47] while ozone is somewhat absorptive of solar radiation it is several-fold more absorptive, in fact, highly absorptive, of terrestrial radiation. Hence, in this case, as in the case of the absorption of radiation by dust, already considered, equation *A* is applicable.

In this equation let a be the coefficient of absorption of the ozone in the isothermal region for solar radiation, and b its coefficient of absorption for earth radiation. To be definite, let $a = 0.02$ and $b = 0.10$ at the time of spot maximum, and for a spot minimum let $a = 0.03$ and $b = 0.15$, quantities that would require really very little ozone. Then, since the earth radiates practically as a full radiator, or black body, at the absolute temperature 256° C., if *T max.* and *T min.* are the equilibrium temperatures at the time of spot maximum and spot minimum, respectively,

$$\left(\frac{T\,\text{max.}}{256}\right)^4 = \frac{521}{500};\ T\,\text{max.} = 258^\circ.65$$

[43] Lyman, *Astrophys. Jr.*, 27, p. 87, 1908.

[44] Lyman (*l. c.*).

[45] Fabry and Buisson, *C. R.*, 156, p. 782, 1913; *Journal de Physique*, 3, p. 196, 1913; Fowler and Strutt, *Proc. Roy. Soc. A.*, 93, p. 577, 1917; Fowle, *Smithsonian Miscellaneous Collections V.*, 68, No. 8, 1917.

[46] *Arkiv för Matematik, Astronomi och Fysik*, 1, p. 395, 1904.

[47] *Annalen der Physik*, 21, p. 305, 1906.

and

$$\left(\frac{T\,\text{min.}}{256}\right)^4 = \frac{2129}{2000};\ T\,\text{min.} = 260^\circ.05$$

That is, under these conditions, and if the solar constant should remain exactly the same, the temperature at the time of spot minimum would be 1°.4 C. warmer than at the time of spot maximum. Hence, even a slight increase in the solar constant at the time of spot maximum might still leave the temperature a trifle cooler than at the time of spot minimum.

Obviously, too, a greater extent of cirrus and cirrus haze during spot maxima than during spot minima (a condition some observers have thought to exist; and due, perhaps, if it does exist, to auroral effect) would also tend to produce the concurrent temperature difference.

Of course, it is not asserted that either the ozone, or the cirrus haze, actually does vary in the manner assumed—observations are inadequate to decide either question; but as such changes are in complete accord with laboratory experiments, it seems that the possibility of their occurrence in nature, and their effects, should be mentioned.

INFLUENCE OF CARBON DIOXIDE ON TEMPERATURES.

It was stated in the early part of this discussion, under the carbon dioxide theory of ice ages, that the question of the possible effect a change in the amount of carbon dioxide in the atmosphere might have on temperatures would be taken up later. The way to this is now open through the above discussion of ozone. Like ozone, carbon dioxide also is more absorptive of terrestrial radiation than of solar energy. Hence, increasing the carbon dioxide in the atmosphere, and thereby increasing its amount in the isothermal region where it can be treated as a shell external to the radiating earth, obviously must have the same general effect on the temperature of the earth as increasing the ozone of this region would have. That is, other things being equal, a greater or less temperature increase would follow the introduction into the atmosphere of a larger amount of carbon dioxide.

Because of the constant mixing caused by vertical convection, it is probable that the percentage of carbon dioxide is very nearly as great at the under surface of the isothermal region as it is at the surface of the earth. If so, then the carbon dioxide of the

isothermal region is equivalent, roughly, to a layer 40 centimetres thick at normal atmospheric pressure. In high latitudes, where the isothermal level is low, the equivalent layer probably is thicker than this, and in equatorial regions probably thinner. Now, according to the experiments of Schlaefer,[48] a layer of carbon dioxide 40 centimetres thick is sufficient to produce very nearly full absorption, and, therefore, no increase in the amount of carbon dioxide in the atmosphere could very much increase its temperature.

An approximate idea of the possible temperature change of the lower atmosphere as a result of the presence of carbon dioxide in the isothermal region can be obtained from known data. Thus, Abbot and Fowle[49] have computed that carbon dioxide may absorb 14 per cent. of the radiation from a black body at the temperature of 282.2° C. absolute. But as this is not many degrees, 25 or so, above the effective temperature of the earth as a radiator, it follows that 14 per cent. is, roughly, the upper limit to which terrestrial radiation can be absorbed by carbon dioxide in the isothermal region, while its absorption of solar radiation is very nearly negligible.

Assuming that the present amount of carbon dioxide in the isothermal region absorbs 1 per cent. of the solar radiation and 10 per cent. of the outgoing earth radiation (values that seem to be, roughly, of the correct order), and using equation *A*, it will be seen, if the experiments here referred to and the assumptions are substantially correct, that doubling or even multiplying by several-fold the present amount of carbon dioxide, which would leave the absorption of solar radiation practically unchanged, and increase the absorption of terrestrial radiation at most to only 14 per cent., could increase the intensity of the radiation received at the surface of the earth about half of 1 per cent., and, therefore, the average temperature by no more than about 1.3° C. Similarly, reducing the carbon dioxide by one-half could decrease the temperature by no more than approximately the same amount, 1.3° C.

It is not certain to what extent the percentage of carbon dioxide in the atmosphere has actually varied during the geologic past, but, if the above reasoning is correct, it seems that surface

[48] *Ann. der Physik*, 16, p. 93, 1905.

[49] *Annals Astrophys. Obsy., Smithsonian Inst.*, vol. ii, p. 172, 1908.

temperatures could never have been much increased above their present values through the action of this particular agent alone. Furthermore, the fact, so far as known, that within the tropics, at least, plant growth was quite as vigorous during the ice ages as it is now, shows that for a very long time, even in the geological sense, carbon dioxide has been abundant in the atmosphere—probably never much less abundant than at present. Hence, it seems likely that a decrease in temperature of a fraction of one degree is all that can reasonably be accounted for in this way.

Finally, if the above reasoning is correct, it seems that changes in the amount of carbon dioxide in the atmosphere might have been a factor in the production of certain climatic changes of the past, but that it could not, of itself, have produced the ice ages.

10. LAND ELEVATION.

Since many changes in land elevation are known to have taken place during the different geologic ages it is necessary, in considering the climates of the past, to inquire what climatic effects such variations in level would of themselves produce. Changes in area will be considered later.

The substantial answer to this question obviously is found in the present effects of elevation on climate. That is to say, the effects of elevation must then have been distant, local, and universal, just as they now are. The distant effects obviously often extended, as they now extend, many hundreds of miles to the leeward of favorably situated high mountain ranges and consisted, as they now consist, essentially in a decrease of precipitation, owing to the extraction of moisture from the atmosphere by forced convection and the consequent tendency towards, or even culmination in, desert conditions beyond. The second or local effects clearly were both an increase in the local precipitation, especially on the windward side, and an average decrease in the temperature, approximately the same as at present,[50] of about 1° C. for each 180 metres, 200 metres, and 250 metres difference in elevation on mountains, hills and plateaus, respectively.

In one important case, namely, when the surface is extensive and snow-covered (probably to some extent also when bare), this relation of temperature decrease between mountain, hill and plateau does not hold, as is obvious from the following considera-

[50] Hann, "Lehrbuch der Meteorologie," 2nd ed., p. 101.

tion. During long, clear winter nights, such as obtain in high latitudes, the surface becomes greatly chilled through comparatively free radiation to the still colder air far above and even to empty space beyond. Hence, the surface air also is chilled and its density made correspondingly greater. It, therefore, flows away to lower levels and at the same time its temperature is increased through increase of pressure, or at least prevented from falling so low as it otherwise would. When the slope is steep, as it usually is on the sides of hills and mountains, this flow clearly must be more or less rapid, especially along narrow valleys or ravines, and, therefore, an approach established, within this portion of the air current, to the adiabatic temperature gradient of about 1° C. per each 100 metres' change in elevation. On the other hand, when the slope is very gentle, as it is over the interior of Greenland and over much of the explored portion of the Antarctic Continent, air drainage necessarily is sluggish and unable to keep pace with the surface cooling. Hence, in such cases the change of temperature with change in elevation (counting from sea level) can be, and usually is, far greater than adiabatic, or 1° C., about, per 100 metres. Hence, such regions, when there are no higher surrounding mountains, can and often do establish: (1) a circulation of the upper air from the ocean to the higher portions of the plateau; (2) a well-defined surface temperature inversion, or, for the first few hundred metres, an increase of temperature with increase of elevation; (3) a slow settling of this air onto the cold surface below; (4) the precipitation, without cloud, of fine snow crystals—" frost snow "; (5) drainage of this chilled and relatively dense air to lower levels; (6) drifting of the snow with the winds and the consequent extension, so far as temperature and other conditions will permit, of the ice-covered or glaciated area.

All these conditions obtain to-day over the two great glaciers that still remain, that of Greenland and that of Antarctica, and, presumably, therefore, must also have obtained to a greater or less extent over all great glacial fields wherever and whenever found. Mere changes in level, therefore, might cause, and doubtless often have caused, somewhat corresponding fluctuations in the climates of both local and leeward regions, and especially in the extent and depth of local glaciations; but this obvious fact does not in the least justify the assumption that either the universal

low temperatures and extensive glaciations of ice ages or the world-wide genial temperatures of the intervening periods had, on the whole, any such origin.

It may be worth while in this connection to call attention to the fact that the thickness or depth of a glacial sheet cannot continue indefinitely to increase with increase of elevation, but, on the contrary, for each given locality must have a level of maximum development, above which it somewhat rapidly decreases.

An important if not the chief contributing factor to this result is the relation of saturation to temperature, illustrated by Fig. 6, which shows by its shaded areas the relative amounts of precipitation for each 5-degree decrease in the temperature of saturated air, assuming the volume to remain constant. Now, as the wind blows up and over a mountain range its temperature decreases somewhat regularly with increase of elevation, and, therefore, at whatever temperature precipitation begins it must, as Fig. 6 shows, continue to decrease in amount as the cloud reaches higher and higher elevations—the effect of the accompanying volume increase on vapor capacity being much less than the effect of the temperature decrease.

If the precipitation always began at the same level, it is obvious that this would be the level not only of initial but also of maximum precipitation. But as the level of initial precipitation actually varies through a considerable range, it follows that the level of maximum catch lies somewhere within this range, probably, too, well within its lower half. Obviously, then, the level of maximum snowfall is not at, nor even close to, the tops of very high mountains, but far down near the lower snow limit.

In addition to this, the generally increasing steepness of the higher reaches causes more frequent avalanches and a greater speed of flow. In short, the higher mountain levels not only catch less snow than do the somewhat lower, but also more rapidly shed what they do catch.

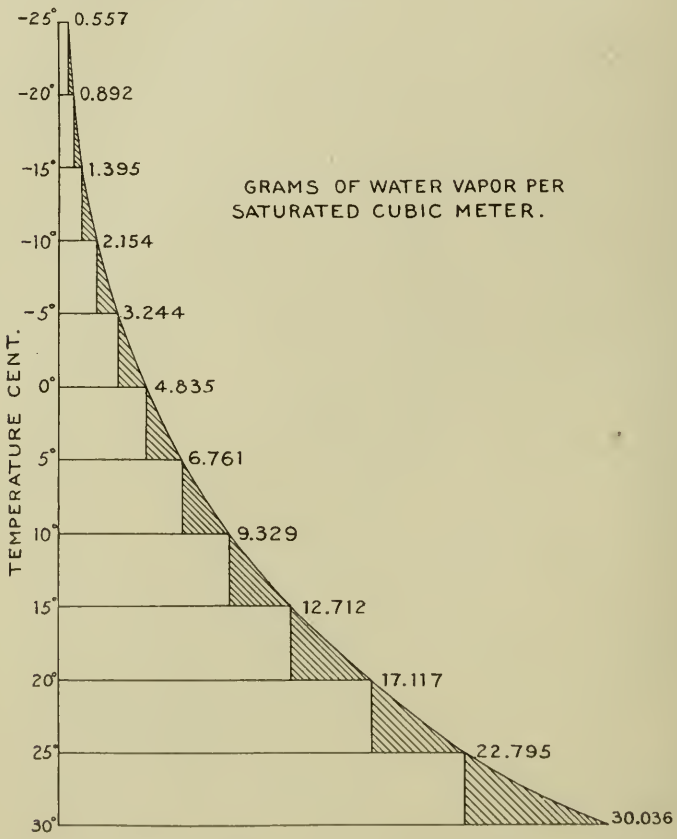
A full discussion of this subject would, of course, require an account of the rate of melting, evaporation, drift, glacial flow, and probably other phenomena; but the above, presumbaly, is sufficient to make it clear why maximum glaciation is not at the greatest elevations, but, on the contrary, at distinctly lower levels.

The universal climatic effect of land elevation, mentioned above, a greater or less lowering of the average temperature over,

perhaps, the entire earth, is a logical consequence of the other two. As is well known, water vapor is by far the world's greatest conservator of heat. Hence, anything that diminishes the average amount of this substance in the atmosphere obviously must somewhat lower surface temperatures.

Now precipitation through which the average humidity is

FIG. 6.



lowered is induced chiefly by vertical convection, a condition which mountain ranges vigorously and extensively produce, (*a*) by mechanical deflection of the winds, (*b*) by updrafts induced on their sides during summer insolation, and (*c*) by the air drainage down their valleys of clear nights. The first two types of convection are very efficient in removing moisture from the

atmosphere, while the third spreads the cold of the exposed higher levels—exposed in the sense that they are above much of the protecting vapor blanket, and, therefore, subjected to more rapid cooling.

Clearly, then, assuming the same total extent of land area, the average temperature of the world is lower when there are a number of high mountain ranges than when there are but few or none—lower because the exposed heights themselves are cold, because they drain their cold air over adjacent regions, and because they dry the atmosphere and thus prevent other portions of the earth from having as efficient protection from heat loss as they otherwise would.

This lowering of the average temperature necessarily decreases the rate of evaporation and the saturation quantity, and, thereby, presumably, further accentuates the cooling. Hence, high mountain ranges, especially when along the coasts of extensive continents, lead to low temperatures, local and windward glaciation, and reduced leeward precipitation. On the other hand, the absence of mountain ranges permits of a relatively humid atmosphere and comparatively high average temperatures.

Conceivably, therefore, the great world-wide climatic changes of the past originated in corresponding changes of level, gradual or cataclysmic. Nevertheless, it seems most improbable (apparently it has not yet been definitely proved one way or the other) that all the several glaciated continents rose and sank together—that there neither is, nor ever was, a simultaneous swing, up and down, of all, or nearly all, continental areas on the one hand and ocean beds on the other; at least not to any such extent as this hypothesis would demand. To be sure, there is much and increasing evidence [51] that in geologically very recent times there has been an increase of sea level relative to that of the land of, roughly, 50 metres in many tropical and subtropical regions where, so far as known, glaciers have never existed. But the simplest interpretation of this appears to be, not that so extensive and such different ocean beds have everywhere sunk to substantially the same extent and at about the same time, but rather that the phenomenon is only the inevitable result of the melting of the extensive glacial sheets of the Quaternary ice age.

[51] Vaughan, *Bull. Amer. Geographic Soc.*, vol. xlvi, p. 426, 1914; Daly, *Amer. Jr. Sci.*, 41, 153, 1916.

It will be assumed, therefore, that all effects, of whatever kind, changes in land elevation may have had on climate, local and leeward, were essentially as above explained, and hence that such changes, however important as contributory factors, constituted neither the sufficient initiating nor the whole sustaining cause either of the glacial or of the interglacial climates if, as is generally believed, these were simultaneously world-wide.

II. CHANGES IN LAND AREA.

In addition to changes in land elevation, and largely because of such changes, there have also been many variations in land extent and, consequently, in the ratio, both local and world-wide, of water surface to land surface. The importance of this phenomena may be inferred from the fact that, according to Schuchert,[52] North America alone has been submerged at least 17 times over areas that range from 154,000 to 4,000,000 square miles, or fully half its present extent. Hence, in a discussion of how the climates of the past have varied, and why, it is necessary to take this additional factor into consideration. An exact or quantitative evaluation of this factor is impossible, but its qualitative effect, and even a rough approximation to its numerical value, may be inferred from the present climates, along the same latitudes, of continents and of islands, and also from the climatic contrast between the northern and the southern hemispheres, as shown in Fig. 8, by the mean annual isotherms. That is, any appreciable increase in the ratio of land to ocean surface presumably accentuated the seasonal contrasts, or made the summers warmer and the winters colder than they otherwise would have been. It must also have accentuated the latitude contrast or made warm regions warmer and cold ones still colder, as is also illustrated by Fig. 8. In short, any increase of land area must, in general, have rendered the local climate more continental and less marine, and all this for the obvious reason that while the solid portions of the earth, rock, sand and soil have no power of avoiding great temperature ranges through either evaporation, convection or flow to other latitudes, all three methods belong abundantly to the ocean.

From this, in turn, since the range of animal species is partly restricted and delimited by the extremes of temperature, and the

[52] *Bull Geol. Soc. America*, vol. xx, p. 601, 1910.

range of vegetable species limited both by these extremes and by the length of the growing season, it follows that an age of great land extent must, through its fossils, give evidence of an excessive zonal climatic contrast, or appear in middle and higher latitudes to have been one of harsh climates, while an age of small land extent, even though the world as a whole had the same average temperature as before, must similarly record a much less zonal contrast and a spread of genial climates to far higher latitudes.

In the above attention has been confined strictly to land surfaces, their elevation and their areas, but continental mountain ranges and plateaus are not the only portions of the earth subject to changes in elevation and extent. Ocean beds and submarine ridges must also vary in both particulars, and, in turn, profoundly modify both local temperatures and zonal contrasts. Some of these ridges doubtless have alternately risen quite to the surface, perhaps at times much higher, and again sunk to considerable depths, and in each case inevitably have produced greater or less climatic changes through the resulting alterations in the oceanic and atmospheric circulations, and, perhaps, in other ways.

12, 13. ATMOSPHERIC AND OCEANIC CIRCULATION.

As everyone knows, practically the entire amount of heat that maintains the surface temperature of the earth is the result of the absorption of solar energy, chiefly by the lower atmosphere and by the various superficial coverings of the surface—vegetation, soil, rock, and water. On the average, the daily supply of this heat per unit area is much greater within the Tropics than it is at higher latitudes, a condition that maintains two distinct, though largely interdependent, systems of perpetual circulation, the atmospheric and the oceanic, that tend to equalize the temperatures of the earth—that keep the tropical regions from becoming unbearably hot and the frigid zones from being unendurably cold.

Clearly, then, any modification of either of these circulations would produce a corresponding change of climates, and the cause of this modification might properly be regarded as the cause of the given climatic changes themselves. But preliminary to a consideration of the probable climatic effects of any such modification it will be necessary, first, briefly to examine both circulations as they now exist.

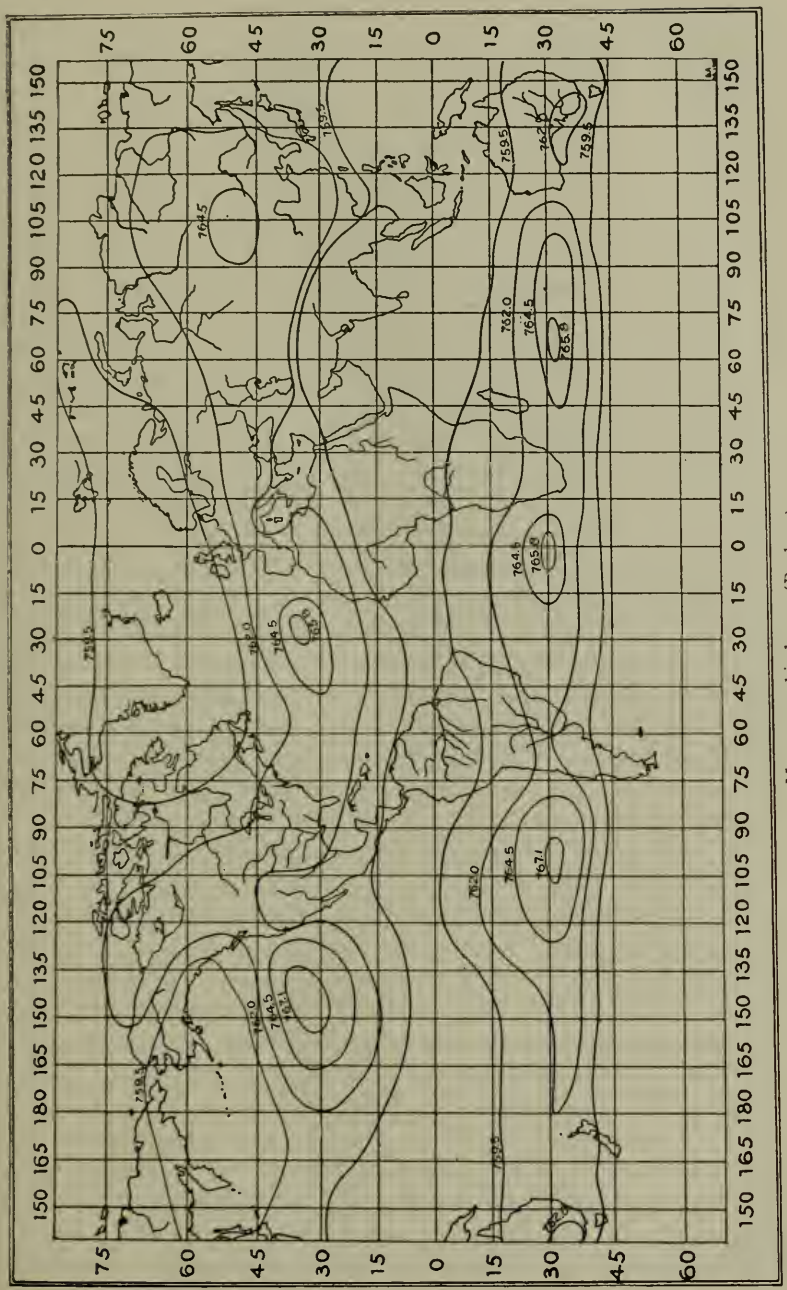
Present Atmospheric and Oceanic Circulations.—Despite innumerable disturbances, great and small, the fundamental circulation of the atmosphere is from equatorial toward polar regions and return, over a surface that moves from west to east with a linear velocity that gradually decreases with increase of latitude. As a result of these conditions the prevailing winds of latitudes higher than 32°, roughly, N. and S., blow from the west towards the east, or, to be exact, have a west-to-east component, while the winds between these latitudes, in the neighborhood, therefore, of the equator and the tropics, commonly blow, in the same general sense as above, from the east towards the west.

Now, the rotation of the earth has forced it to take the shape of an oblate spheroid—has bulged it at the equator and flattened it at the poles—and this distortion from the perfect sphere is such that an object on the surface is in equilibrium, so far as moving north or south is concerned, only when it has the same angular velocity about the axis of the earth that the earth itself has, or, in short, when it has no motion over the surface east or west. Obviously, then, an object moving from west to east, or with an angular velocity exceeding that of the earth, would be in equilibrium on a bulge greater than that which actually exists, and hence all winds with an eastward component, and, therefore, as stated, the prevailing winds outside latitudes 32° N. and S., must tend to climb up towards the equator. On the other hand, an object moving from east to west, or with an angular velocity less than that of the earth, as do the prevailing winds between latitudes 32° N. and S., must tend to slide down towards the adjacent or nearest pole. These opposite drifts of the winds, therefore, the drift of the winds of high latitudes toward the equator and the drift of the tropical winds toward the adjacent pole, obviously have produced the two belts of relatively high barometric pressure that roughly parallel the equator, the one at about latitude 32° N.; the other at approximately latitude 32° S.

Each belt of high pressure is greatly disturbed where it crosses a continental area, owing chiefly to temperature inequalities, but it also happens that even on the oceans the belts are of unequal intensity, and, what is of especial importance, have relatively fixed absolute pressure maxima or anticyclonic centres.

These permanent or nearly permanent centres of high pressure, or centres of action as they have been called, are five in

FIG. 7.



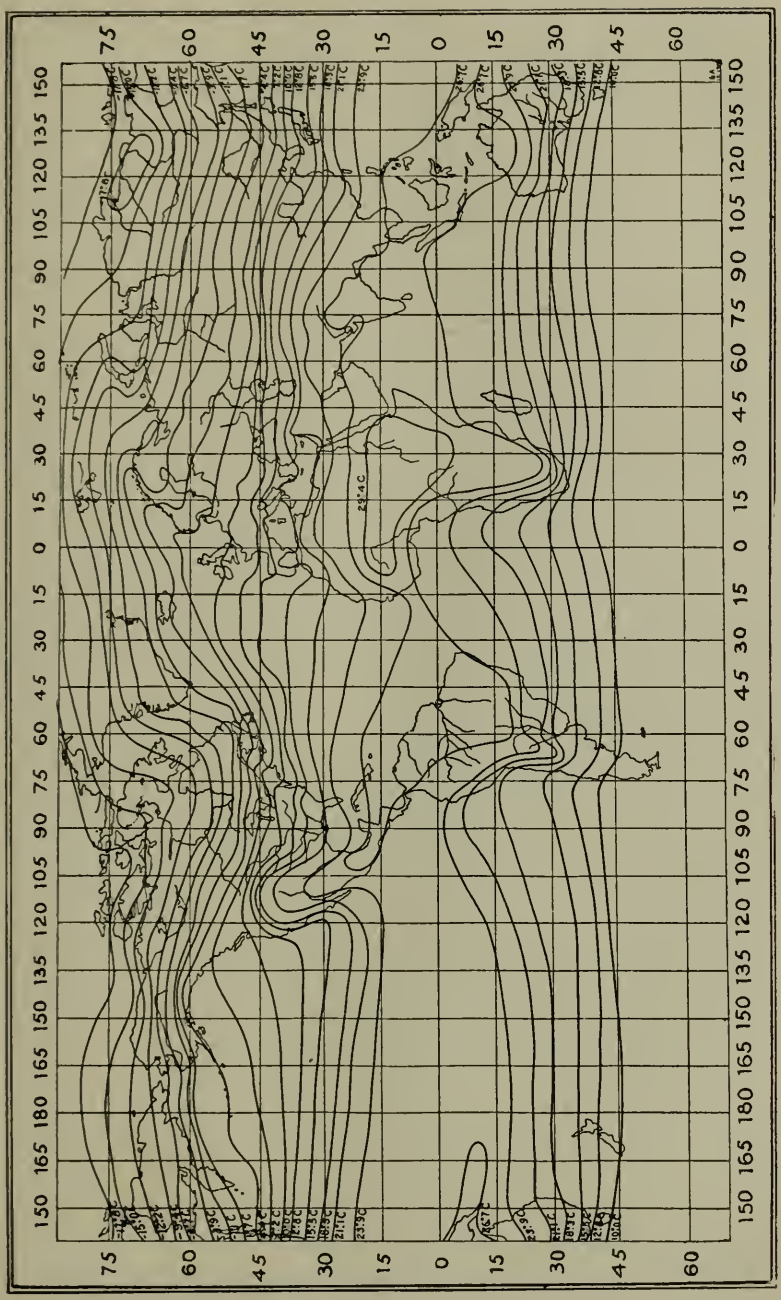
Mean annual isobars. (Buchan.)

number, as a reference to Fig. 7 will show; two in the northern hemisphere, one off the coast of southern California, the other near the Azores; and three in the southern hemisphere, one off the coast of Chile, another just west of South Africa, and a third between South Africa and Australia. Further, as is shown by Fig. 8, there is, in the region of each of these permanent anticyclonic centres, a marked equatorial deflection of the annual average isotherms, showing clearly that while each high pressure belt as a whole is caused by the mechanical squeeze of the opposite air drifts, above explained, the additional pressure that produces each maximum is a result of the local relatively low temperature, which causes a corresponding contraction and, therefore, increased density of the local atmosphere. And, finally, these particular low air temperatures in turn are caused by cold ocean currents, as is obvious from Fig. 9, and again from Fig. 10, which show the interrelations here considered between barometric pressure, air isotherms, and ocean currents.

That both the mere existence of these anticyclonic centres and their several geographic locations are of great importance to the climates of neighboring regions, through their directing influence on the prevailing winds, is obvious from Figs. 11 and 12, that give the directions and indicate the average force and steadiness of ocean winds at different seasons. But all this influence on the winds, however vital to many a local climate, can properly be said to be only one of the important climatic effects of the existing ocean currents.

In addition to the several permanent anticyclonic centres there are, also (see Figs. 11 and 12), one permanent cyclonic centre, the Icelandic "low," and one semi-permanent or winter cyclonic centre, the Aleutian "low," both of which are strongly influenced by ocean currents, the first by the Gulf Stream and the second by the Japan Current. The Icelandic "low" results from the temperature contrast between the air over the relatively warm water and that over the glacial fields of Greenland and Iceland, in consequence of which there is established a circulation in the sense of an overflow from the warm region and counter underflows from both the adjacent cold regions. This thermally induced circulation in conjunction with the rotation of the earth produces cyclonic conditions, and as the temperature contrasts are permanent (the Icelandic and the Greenland glaciers remain

FIG. 8.



Mean annual isotherms. (Buchan.)

throughout the year and indefinitely), the cyclonic conditions themselves of this region are also permanent.

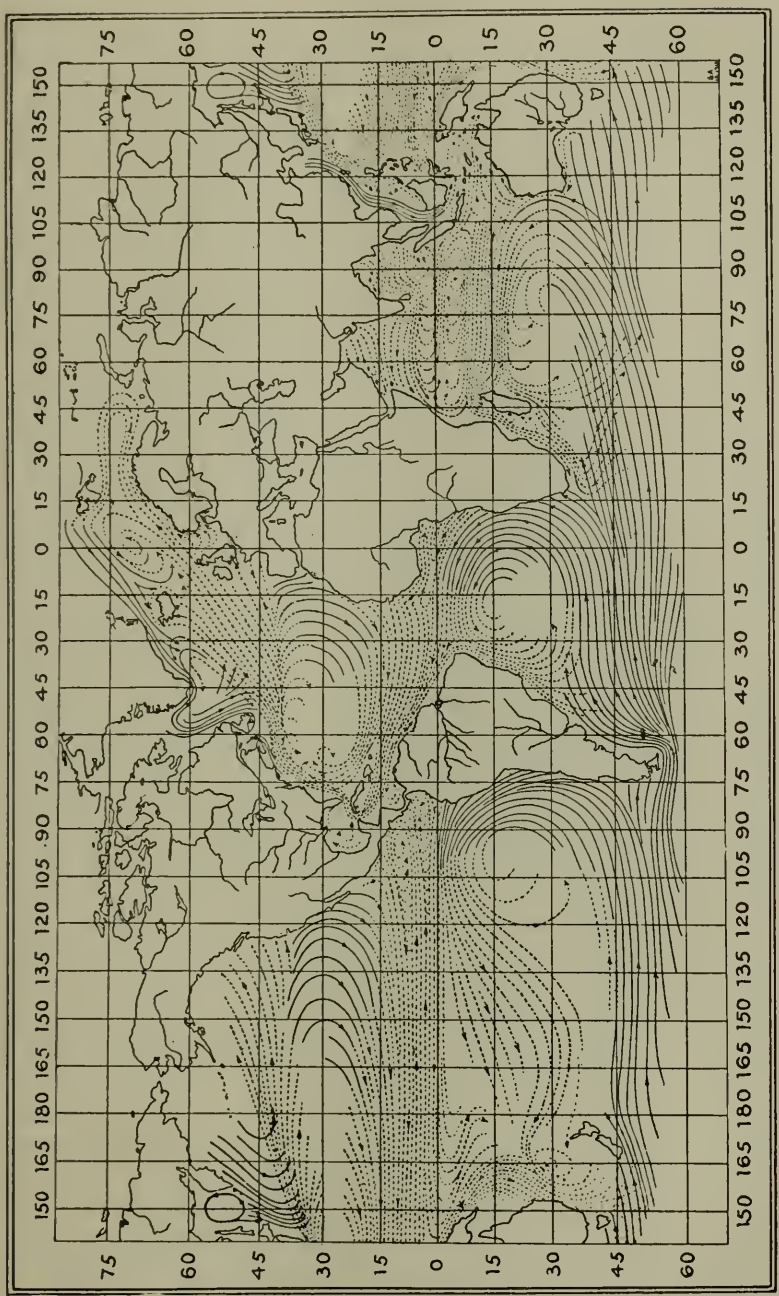
The Aleutian "low," on the contrary, that is flanked by the Alaskan peninsula and the peninsulas of northeastern Siberia, has a circulation similar to that of the Icelandic "low," and for similar reasons, only while the adjacent land areas are covered with ice and snow and, therefore, are relatively cold. In the spring, when the snow melts away, the cyclonic conditions also disappear, there then being nothing to sustain them.

But the formation and geographic location of the above cyclonic and anticyclonic conditions—direction and force of winds, nature and frequency of storms, and the like—do not exhaust the more important climatic effects of existing ocean currents, as a glance at the annual average isotherms and ocean currents of the North Atlantic (Fig. 10) will show. In fact, the January isotherm of Chicago, Buffalo, and Boston (very approximately on the latitude of Rome), though not particularly cold, passes, under the influence of the Gulf Stream, through Iceland and on well beyond the Arctic Circle to the north of Norway and Sweden; while, under the same influence, frost is practically unknown and semitropical vegetation flourishes on the Scilly Isles in the latitude of northern Newfoundland. Similarly, it is said that because of the Japan Current frost rarely, if ever, occurs on one or two of the Aleutian islands.

Obviously, then, as the above several examples show, the ocean currents, driven by the winds, deflected by the rotation of the earth and by continental and island barriers, and otherwise modified by various minor causes, are both directly and indirectly of the greatest importance to the climates of many parts of the world; directly through the immense thermal interchange they establish between the torrid and the frigid zones, and indirectly through the centres of action, the permanent and semi-permanent "highs" and "lows," they create and maintain.

Possible Changes in the Oceanic Circulation and the Obvious Climatic Results.—Clearly, if the immense system of hot-water heating by which the temperature of the whole surface of the earth tends to become equalized should be greatly modified, say by the opening of a valve here or the closing of another there, correspondingly great climatic modifications surely would have to follow. And there are several, perhaps many, such valves that

FIG. 9.



Ocean currents; full lines, cold; dotted lines, warm.

have been opened or closed, irregularly, and from time to time, since the beginning of geological records. One such valve now partially open, perhaps at one time closed and at another still wider open than at present, lies between South America and the Antarctic continent. Another, now but a little way open, is Bering Strait, which doubtless has greatly changed from one to another geologic age. Still another, now wholly closed, but at one time probably wide open, is the Central American region between the Caribbean Sea and the Pacific Ocean. This particular valve, if now widely opened, would, on the one hand, obliterate the Gulf Stream proper and probably diminish the Antilles current, and, on the other, greatly increase the Japan Current; and, of course, in each case induce widespread and marked climatic changes. Yet another valve, now rather wide open, that merits special mention, a valve that may have suffered many changes and have undergone its latest opening only in recent times, geologically speaking, is found in that ridge which by way of Iceland and the Faroe Islands connects Greenland with north Scotland.

With this Greenland-Scotland valve closed and even with all the other valves, channels of flow and deflecting obstructions, substantially as they now are, it is well-nigh certain that the Icelandic "low" would shift to some point between Greenland and Newfoundland; that Labrador and the Hudson Bay region would receive a greatly increased precipitation; that the Norwegian Sea would become largely, if not wholly, ice-covered; and, finally, that Norway and Sweden, since they have the same latitude as Greenland, would be swept by winds of practically Arctic temperature and, therefore, eventually would become, like Greenland itself, almost wholly ice-capped. Indeed, any decided change in either the average intensity or average position of the Icelandic "low," if continued for even a few weeks, seems to produce a marked influence on the weather of west and north Europe. In general, whenever the average position of this "low" during a winter month is considerably to the west of its normal place, as occasionally happens, the average temperature of north Europe is likely to be several degrees below normal.[53] That is, the above conclusion that a permanent or age-long shift of the Icelandic "low" far to the west of its present position would

[53] Hann, "Handbuch der Meteorologie," 3rd ed., pp. 632–3, 637, 639.

FIG. 10.

Superposition of ocean currents on mean annual isotherms and isobars.

lead to, or, at least, permit, the reglaciation of portions of north Europe appears to be abundantly supported by direct observation. Nor would these be all the profound climatic changes that probably, indeed well-nigh certainly, would follow the closing of the Greenland-Scotland valve, but they are sufficient, if granted, to indicate how vitally important the direction and magnitude of the ocean currents are to our climates and to local glaciation.

Doubtless many other valves have contributed their part in the control of the earth's great water circulation and the regulation of its climatic details, but it would be tedious to take all of them up individually, and for the present purpose unnecessary, since it is desired here only to make clear the fact that oceanic circulation is a vital factor in the production and control of many a local climate.

14. SURFACE COVERING.

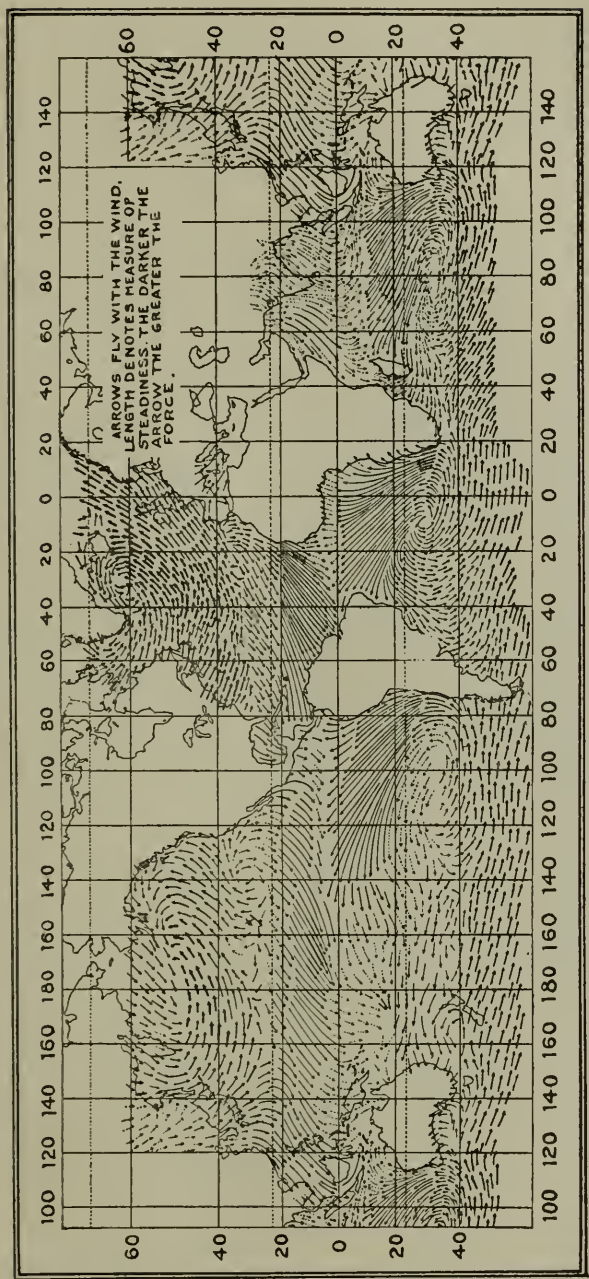
The contrast between land and water in respect to their climatic effects obviously is largely due to the inequality of their surfaces both as radiators and as absorbers. The values of these properties are approximately known for the ocean, but not for the continents. In fact, there are no fixed values for land areas; nor can there be, since their surfaces undergo many and great changes. Bare soil, luxuriant vegetation, and snow, for instance, are among the surface coverings that have very unequal powers of radiation and absorption; and, therefore, the changes from one to the other over any extensive area necessarily is a matter of climatic importance.

To illustrate an extreme, but seemingly possible, climatic effect due to change of surface, assume:

(1) That continental areas are unusually extensive; (2) that mountains are abundant and high; (3) that during a period of a few years volcanic explosions are frequent (one a year, say) and of such nature as to put large quantities of dust in the upper atmosphere, as did the Krakatoa and other explosions of historic times.

The low temperatures due to the volcanic dust would lead to an abnormal extent of continental snow covering, and this, in turn, by its power of reflection, would render the insolation correspondingly less effective—would virtually decrease the solar constant, for all the reflected radiation that passes directly to

FIG. II.



Normal wind direction and velocity, January and February. (Köppen.)

space had as well never have reached the earth at all, so far as producing any heating is concerned. In this way an ice covering of the land areas, far more extensive than previously existed, might be initiated by the volcanic explosions, and then perpetuated over long periods, if not even added to, by the highly reflecting snow cover.

CHRONOLOGICAL RELATION OF GEOLOGICAL EVENTS.

It is rarely possible to state in terms of years even approximately when any prehistoric geological event occurred or, similarly, to measure its duration, but it is possible in large measure accurately to decipher the order of their occurrence and to learn their chronological relations to each other.

Our present knowledge of geological chronology has been summarized by several geologists—Schuchert in his "Climates of Geologic Time," [54] for instance—all of whom, though differing in details, have much in common. In the course of his summary Schuchert [55] says:

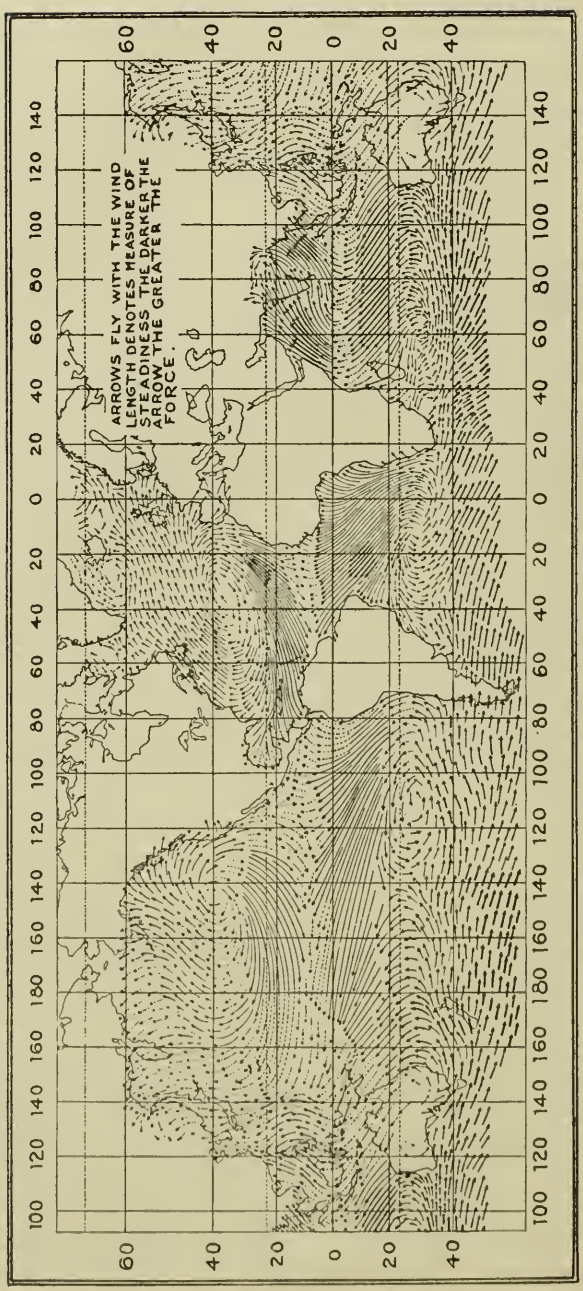
> The data at hand show that the earth since the beginning of geologic history has periodically undergone more or less widespread glaciation, and that the cold climates have been of short geologic duration. So far as known, there were seven periods of decided temperature changes, and of these at least four were glacial climates. The greatest intensity of these reduced temperatures varied between the hemispheres, for in earliest Proterozoic and Pleistocene time it lay in the northern, while in late Proterozoic and Permic time it was more equatorial than boreal. The three other probable periods of cooled climates are as yet too little known to make out their centres of greatest intensity.
>
> Of the four more or less well-determined glacial periods, at least three (the earliest Proterozoic, Permic, and Pleistocene) occurred during or directly after times of intensive mountain-making, while the fourth (late Proterozoic) apparently also followed a period of elevation. The Table Mountain tillites of South Africa, if correctly correlated, fall in with the time of the making of the great Caledonian Mountains in the northern hemisphere. On the other hand, the very marked and world-wide mountain-making period, with decided volcanic activity, during late Mesozoic and earliest Eocene times, was not accompanied by a glacial climate, but only a cooled one. The cooled period of the Liassic also followed a mountain-making period, that of late Triassic time. We may therefore state that cooled and cold climates, as a rule, occur during or immediately follow periods of marked mountain-making—a conclusion also arrived at independently by Ramsay.[56]

[54] Carnegie Institution of Washington, Publication No. 192, p. 285, 1914.
[55] *L. C.*, p. 286.
[56] Oversigt af Finska Vet.-Soc. Forhandl., vol. lii, pp. 1–48, 1910.

From the above, with which most geologists are in accord, it appears that neither cold climates nor even cool climates ever occurred except when mountains were either building or at least geologically young, and, also, so far as may be judged from the Strand line of North America, when the ratio of land area to ocean was relatively large. This coincidence appears to have occurred too frequently to admit of the idea that it was mere chance or due to anything less than some sort of a casual relation—surely not that the cold climates produced the mountains, nor necessarily that mountain building was wholly responsible for glaciation, but rather that crustal uplift and the other geological phenomena, whatever they were, that went with it so combined as to produce at one time a small and at another a great climatic change. If, also, as supported by geological evidence, vulcanism (only violently explosive volcanoes are of especial climatological importance), was, in general, most active during the epochs of mountain building, but unequally so for different mountain systems, then it follows that at each of these particular times there obtained to a greater or less degree precisely those formations and conditions—high mountains, extensive land area, restricted oceanic circulation and much volcanic dust—which are known to be effective to-day in reducing temperature, and which, presumably, are entirely sufficient, when properly coöperating, to produce not only a cool climate, such as, relatively speaking, now prevails, but even climates that are severely glacial. Which of these several causes was most effective in producing the low temperatures of any given age in the past (they must have been unequally active at different epochs) it may be impossible to determine, but the brief duration of distinctly glacial ages in comparison to the much longer periods when mild climates prevailed seems strongly to favor the assumption that vigorous vulcanism was often at least an important contributing factor.

But whatever else geologic chronology, as it is now understood, may teach in regard to the climatic changes of the past, the practical coincidence of cold ages with mountain building epochs appears at once and irretrievably to negative the entire group of cosmical ice-age theories—those that assume all great climatic changes to depend upon the sun, a condition in space, or anything else wholly outside the earth. Such theories, any solar theory, for instance, must also assume that those external changes, solar

FIG. 12.



Normal wind direction and velocity, July and August. (Köppen.)

changes, say, which caused a marked lowering of terrestrial temperatures, occurred only at or about the times of mountain building. That is, they must assume that either (*a*) the solar changes caused the mountain building, or (*b*) that mountain building caused the solar changes, or, finally (*c*) that both had some unknown but simultaneously acting common cause. But each of these assumptions is wholly untenable—it has no support whatever in the logic of cause and effect—and, therefore, it seems that any theory that implicitly or otherwise is definitely hung on the horns of this dilemma, as is every cosmical ice-age theory, nebular, or what not, must itself be abandoned.

This is not intended in the least to deny or even to question the existence of small solar changes of comparatively short duration, but only to emphasize the fact that phenomena within the earth itself suffice to modify its own climate, and that there is much and accumulating evidence that these and these alone have actually caused great changes time and again in the geologic past: done so by building mountains, and by tearing them down; by emerging continents, and by submerging them; by restricting ocean currents, and by making wide their paths—actions no doubt frequently accompanied by atmospheres at times heavily charged with the dust from violent volcanic activity and at other times cleared of foreign substances.

CONCLUSION.

It appears from various considerations that, with a constant or nearly constant output of solar energy, the earth itself possesses the inherent ability to profoundly modify its own climates, whether only local or world-wide. Thus, a mere change in land elevation, whether of plateau or of mountain range, a thing that appears often to have happened, must alter both the local and the leeward climates, and, by reducing the general humidity, somewhat lower the average temperature. Besides, a change in land elevation of any considerable extent is pretty certain to be accompanied by a somewhat corresponding variation in continental area, and such modification of shore lines and ocean beds that greater or less changes must follow in the directions, temperatures, and magnitudes of ocean currents, in the location and intensity of permanent "highs" and permanent "lows," in the direction, force and temperature of local winds, in the amount

and kind of local precipitation, and in a host of other meteorological phenomena.

Again, as the laws of radiation indicate must be true, and as observations, at least back to 1750, the date of the earliest reliable records, show, the temperature of the lower atmosphere depends in part upon the amount of dust in the upper air, in the sense that when this amount is great the average temperature at the surface of the earth is below normal, and when the dust is absent this temperature is comparatively high. Hence, as there appear to have been several periods of great volcanic activity in the past with intervening periods of volcanic quiescence, it is inferred that volcanic dust in the upper atmosphere was at least one important factor in some, if not all, of the great and universal climatic changes that have left their records in abandoned beaches and forsaken moraines.

How these various causes of climatic changes were related to each other during the geologic past is not yet entirely clear. This the geologist, most interested and most competent to judge, must determine. May it be that extensive upheavals and great volcanic activity often were synchronous? If so, the climatic effects of each obviously were added to those of the other, and hence it may be that the greatest of our past climatic changes were caused by the roughly synchronous variations in continental level and volcanic activity; universal cold periods coming with increase in vulcanism, increase in elevation and the obstruction of interzonal oceanic circulation; universal mild periods when volcanic dust seldom veiled the skies, when the continents had sunk or been eroded to low levels and when there was great freedom of oceanic circulation from equatorial to polar regions; mild universal climatic oscillations with temporary changes in vulcanism; and mere local climatic changes with variations in such local climatic controls as near-by elevations and neighboring ocean currents. Finally, as the past is the pledge of the future, it is but reasonable to suppose that the world is yet to know many another climatic change, in an irregular but well-nigh endless series, often local and usually slight, though always important, but occasionally, it may be, as in the ages gone—whether towards the auspiciously genial or into the fatefully disastrous—universal, profound and momentous.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

ANNUAL REPORT OF THE DIRECTOR OF THE BUREAU OF STANDARDS.[1]

[ABSTRACT.]

A REVIEW of the work of the National Bureau of Standards for the year ended June 30, 1919, is given in the Annual Report of the Director of the Bureau of Standards at Washington. The report describes the functions of the Bureau in connection with standards and standardization, and contains a chart and description of the several classes of standards dealt with. The Director also gives a clear idea of the relation of the Bureau's work to the general public, to the industries, and to the Government, and includes a special statement of the military work of the year. Brief statements are made upon practically all of the special researches and lines of testing completed or under way at the Bureau. The list of these topics occupies 12 pages in the table of contents.

The Bureau is organized in 64 scientific and technical sections and 20 clerical, construction, and operative sections. During the year the Bureau has issued 51 publications, not including reprintings, 36 of which were new and 15 revisions of previous publications. In the several laboratories of the Bureau more than 131,000 tests were made during the year. The appropriations for the year, including special funds for war investigations, were approximately $3,000,000. A noteworthy event of the year included the completion of the industrial laboratory in which will be housed the divisions having to do with researches and tests of structural materials. The building also includes a commodious kiln house for use, among other purposes, of the ceramics division in the experimental production of new clay products and for general experimental purposes.

The report comprises 293 pages and may be obtained as long as free copies are available by addressing the Bureau of Standards, Washington, D. C.

* Communicated by the Director.

[1] Miscellaneous Publication No. 40.

SPECIFICATIONS FOR THE MANUFACTURE AND INSTALLATION OF RAILROAD TRACK SCALES.[2]

[ABSTRACT.]

THE active coöperation between the Bureau of Standards, the Railroad Administration, the State of Minnesota, the American Railroad Association, the American Railway Engineering Association, the Scale Manufacturers' Association, and the National Scale Men's Association, has resulted in new standard specifications for railroad track scales which are satisfactory to all concerned.

The private purchaser is now in a position to secure authoritative information on what he should buy and is enabled to know what he is getting. Adequate standardized scales for all ordinary purposes should, therefore, replace the needless multiplicity of designs, many of which were inadequate.

The subject has been handled from a national viewpoint. This was somewhat difficult as conditions vary widely throughout the country, but the value of the completed work is correspondingly greater. What is of particular importance, all interests have for the first time agreed on very complete and detailed standard specifications for track scales which are satisfactory to all concerned. These specifications will, therefore, form the basis for standardizing railroad track scales for ordinary weighing requirements.

The provisions have been drawn to secure the economy of standardized construction without the detrimental features sometimes associated with over-standardization. The general adoption of these specifications should greatly promote the use of proper scales and weighing facilities and at a minimum cost. This will aid railroads, private owners, industries, and the Federal and State governments which have concerned themselves with this important subject. The weighing of carload freight on American railroads can thus be greatly improved and brought to a high standard of practical efficiency.

[2] Circular No. 83

THE PROPERTIES OF AMERICAN BOND CLAYS AND THEIR USE IN GRAPHITE CRUCIBLES AND GLASS POTS.[3]

By A. V. Bleininger.

[ABSTRACT.]

THE properties of American bond clays are described in detail and expressed through characteristic numerical values with special reference to their burning behavior. It is shown that materials equal in quality to those formerly imported from Germany are available and that by suitable blending any desired combination of properties can be readily produced. The characteristics of natural and artificial graphite are described and means suggested for the control of crucible mixtures. The fact is brought out that the main advantage in the use of German glass pot clay consists in its low fire shrinkage and suggestions are made for obtaining similar conditions with the use of domestic materials and with increased resistance to corrosion. The compositions and the preparation of semi-porcelain and porcelain glass pots are given. The method of casting glass pots as practiced at the Pittsburgh laboratory of the Bureau of Standards is also described.

RECOMMENDED SPECIFICATION FOR BASIC CARBONATE.[4]

[ABSTRACT.]

THIS specification was prepared and recommended by the U. S. Interdepartmental Committee on Paint Specification Standardization, August 11, 1919. This committee was appointed at the suggestion of the Secretary of Commerce, and consisted of representatives of the War, Navy, Agriculture, Interior, Post Office, Treasury, and Commerce Departments, the Railroad Administration, the Panama Canal, and the Educational Bureau of the Paint Manufacturers' Association of the United States. The committee submitted a preliminary draft of this specification to a number of representatives of the paint and varnish industry, including all of the large manufacturers of white lead, and gave careful consideration to the replies received in time.

This specification gives chemical and physical requirements for dry basic carbonate white lead and basic carbonate white lead ground to a paste in linseed oil. Methods of sampling and methods of testing both dry pigment and paste are made part of the specification. For details the original should be consulted.

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[3] Technical Paper 144.

[4] Circular No. 84.

Relative Contribution of the Staple Commodities to the National Food Consumption. RAYMOND PEARL. (*Proceedings of the American Philosophical Society,* 1919, lviii, 182–222.)—Over one-half of the *protein* eaten by the American people is contained in animal foods other than fish; 36 per cent. of the protein ingested is normally derived from grains (including 28 per cent. from wheat), 26 per cent. from meats, 20 per cent. from dairy products, and approximately 7 per cent. from poultry and eggs. Of the *fat* eaten, 51 per cent. is furnished by meats (including 40 per cent. supplied by pork and its products), 27 per cent. by dairy products, 12 per cent. by oils and nuts. Of the *carbohydrate* eaten, 56 per cent. is derived from grains, 26 per cent. is taken as sugars; vegetables, fruits, and dairy products contribute smaller per cents to the total. Grains supply 35 per cent. of the *energy* (calories) in the nation's diet, meats 22 per cent., dairy products 15 per cent., sugars 13 per cent., vegetables 5 per cent., fruits 2 per cent., poultry 2 per cent., vegetable oils and nuts 5 per cent. The average daily food consumption by an adult man is 114 grammes protein, 127 grammes fat, and 433 grammes carbohydrate; this gives an average daily consumption of 3424 calories.

J. S. H.

Application of Sanitary Science to the Great War in the Zone of the Army. BAILEY K. ASHFORD. (*Proceedings of the American Philosophical Society,* 1919, lviii, 317–336.)—Sanitary science has reduced the number of deaths from disease in the army during war-time. The number of deaths per 1000 of strength annually was: Civil War, 65; Spanish-American War, 30; Great War, 14.8, including 12 due to epidemic pneumonia. Protective vaccination against typhoid and its congeners was so efficient that but 17 cases of typhoid and 10 cases of para-typhoid developed in the First American Army of 1,000,000 men up to January 1, 1919. Administration of a protective dose of tetanus antitoxin to all the wounded reduced the percentage of cases of tetanus (lock-jaw) in the wounded from 3.2 per cent. in 1914 to a small fraction of 1 per cent. in 1917. In the trenches and the field, treatment of the water in a Lyster bag with hypochlorite was used to obtain a safe supply of drinking water. In open warfare, sanitation was reduced to a mere shred. Soakage pits were used for disposal of the urine. Latrines were rendered fly-proof. In the trenches latrines for feces were located in blind off-shoots from communicating trenches; they were either deep pits or else provided with buckets which were emptied, with the garbage from the food, into adjacent shell holes at night. In the back area, the British used bucket latrines for feces; each bucket contained a small amount of cresol; twice a day 20 per cent. of saw-dust was added to each bucket which was then emptied into an incinerator.

J. S. H.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

THE HYDROLYSIS OF STIZOLOBIN, THE GLOBULIN OF THE CHINESE VELVET BEAN, STIZOLOBIN NIVEUM.[1]

By D. Breese Jones and Carl O. Johns.

[ABSTRACT.]

STIZOLOBIN, the globulin of the Chinese velvet bean, was hydrolyzed and the resulting amino acids determined quantitatively. Glutaminic acid was isolated directly as the hydrochloride, and the remaining amino acids separated, for the greater part, by the usual ester method. A modification of the customary method for the determination of proline is described which does not involve the ester method. Aspartic, and hydroxy-glutaminic acids were determined in a separate hydrolysis according to the method of H. D. Dakin. A striking result of the use of this method is the extraordinarily high percentage of aspartic acid obtained, namely, 9.23 per cent., while only 5.70 per cent was obtained from the esters.

The following percentages of amino acids were obtained as a result of this hydrolysis. Glycine, 1.66; alanine, 2.41; valine, 2.88; leucine, 9.02; phenylalaine, 3.10; aspartic acid, 9.23; glutaminic acid, 14.59; hydroxy-glutaminic acid, 2.81; serine, 0.67; tyrosine, 6.24; cystine, 1.13; arginine, 7.14; histidine, 2.27; lysine; 8.51; ammonia, 1.55. The presence of tryptophane was shown.

PHTHALIC ANHYDRIDE. II. THE MELTING POINT OF PURE PHTHALIC ANHYDRIDE. THE SYSTEM: PHTHALIC ANHYDRIDE—PHTHALIC ACID.[2]

By K. P. Monroe.

[ABSTRACT.]

VERY pure phthalic anhydride was prepared by re-sublimation in vacuo in the presence of P_2O_5. The melting point was estab-

* Communicated by the Chief of the Bureau.

[1] Published in the *Journal of Biological Chemistry*, vol. xl, No. 2, December, 1919.

[2] Published in the *Journal of Industrial and Engineering Chemistry*, vol. xi, No. 12, December, 1919, p. 1116.

lished as 130.84°, while the eutectic temperature of phthalic anhydride and phthalic acid was determined to be 129.74°. The freezing point curves for the system, phthalic anhydride-phthalic acid, were explored over the somewhat limited region of the system to which the experimental method was applicable. By plotting reciprocals of absolute freezing points against logarithms of mole fractions of acid the melting point of pure phthalic acid, which can not be determined directly, was indicated to be 208 ± 2°.

PHTHALIC ANHYDRIDE. III. THE SYSTEM: NAPHTHALENE —PHTHALIC ANHYDRIDE.[3]

By K. P. Monroe.

[ABSTRACT.]

THE freezing point curves of this system were determined in an apparatus specially designed to obviate difficulties encountered in systems of substances which sublime readily at the melting point. Observed freezing points on one curve (naphthalene as solid phase) agreed closely with calculated values based upon the Schröder-Le Chatelier formula; the other curve (phthalic anhydride as solid phase) was tested by re-casting this formula so that the molar heat of fusion of phthalic anhydride could be calculated from the individual points. Satisfactory agreement was observed, indicating that this curve, as well as the former, conforms to the law of ideal systems. The molar heat of fusion so calculated was 5480 calories.

Damage to France During the War. ANON. (*Steam*, vol. xxiii, No. 3, p. 76, September, 1919.)—A hasty investigation since the signing of the armistice shows the total destruction in France of something like 500,000 buildings damaged and at least 250,000 building completely destroyed. This destruction of buildings is estimated at $6,000,000,000 by the Government engineers. The total cost of repairing and replacing the used or destroyed public works is estimated at about $2,000,000,000. The Nord railroad alone has lost 1731 bridges and 338 stations. It is estimated that 250,000 acres are rendered uncultivatable by the war. The total damage in the north of France, including, buildings, agriculture, industry, furniture and public works, is estimated at about $13,000,000,000.

R.

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[3] Published in the *Journal of Industrial and Engineering Chemistry*, vol. xi, No. 12 December, 1919, p. 1119.

NOTES FROM THE U. S. BUREAU OF MINES *

SENSITIVENESS OF EXPLOSIVES TO FRICTIONAL IMPACT.

By S. P. Howell.

Many commercial explosives may be exploded by severe and prolonged friction, some being more sensitive than others in this regard. Explosives containing potassium chlorate are especially likely to explode under such conditions. Tests to determine sensitivity to frictional impact having previously been made by unsatisfactory equipment, a pendulum friction device, described in Technical Paper 234, Bureau of Mines, that permits uniformity of execution, was designed and built. The results of tests with this device on a large number of explosives and under varied conditions are given in the publication noted above. They indicate that the tests are not too severe, since potassium chlorate explosives which failed to pass the test exploded prematurely in commercial use; all explosives of this type being extremely sensitive to frictional impact. Those potassium chlorate explosives that passed the tests were rendered sufficiently insensitive to friction by adding an adequate quantity of mineral oil, vegetable oils, and aromatic nitro compounds, or by reducing the potassium chlorate to a small percentage. The sensitiveness of such explosives to friction is greatly increased by the presence of pyrite-bearing coal. Black blasting and ignition powders, blasting gelatin, ammonia dynamites, and organic nitrate explosives are not as sensitive to friction impact as the nitro-glycerin and gelatin dynamites.

APPROXIMATE QUANTITATIVE MICROSCOPY OF POWDERED ORES.

By Will H. Coghill and J. P. Bonardi.

In ascertaining the physical and chemical properties of any given ore preparatory to prescribing the best method for its concentration, as many methods of gathering information as are feasible should be employed, so that all significant properties may be detected. Hynes, while working with one of the writers sev-

* Communicated by the Director.

eral years ago, developed a method of sorting under a reading glass, and applied it to sized grains as small as 28 mesh. In Technical Paper 211, Bureau of Mines, under the title given above, we show how to improve on Hynes' method by using an offset device which makes the counting of grains smaller than 28 mesh much less irksome. A binocular microscope is preferable to the monocular instrument used in the earlier methods. Close and thorough screen sizing is essential. The separate screen products must be washed and dried so as to present clean and bright mineral surfaces. A wetting solution that contains saponin or soap is best for wet screening of the finer sizes, and re-screening may be necessary to separate particles grouped by cohesion and adhesion. The finer products should be spread over the microscope plate by the use of a fine sieve. Orientation for each reading is made by adjusting the glass slide along a ruled offset. The advantages claimed for the method there described are its low cost, rapidity, that it gives a closer approximation to chemical analysis than is obtainable by the earlier methods, and serves as a guide to the metallurgist in mill operations. A typical record sheet is given, and the method is illustrated by applying it to the "grading up" of molybdenite concentrates, followed by an interpretation of the results and their application to this metallurgical problem.

ABATEMENT OF CORROSION IN CENTRAL HEATING SYSTEMS.

By F. N. Speller.

WHETHER hot water or steam is used as the medium for conveying heat to the consumer, a heavy toll in upkeep must be faced sooner or later if the corrosion of the piping has not been taken into account in the design of the plant. The main source of corrosion has been traced to dissolved gases brought into the system either with the feed water for the boiler or through leaks in the return lines under a pressure below that of the atmosphere. In a recent paper by F. N. Speller and R. G. Knowland (Preservation of hot water supply pipes in theory and practice, Proc. Am. Soc. Heat. and Vent. Eng., vol xxiv, 1918, pp. 217–240) an outline of the fundamental reactions of corrosion is given. It has been well established that the factors which cause corrosion rather than any commercial difference in the composition of the pipe, de-

termine the rate of corrosion, and a considerable number of service tests of the corrosion of pipe carrying hot water indicates practically no difference, on the whole, among reputable makers of wrought iron and steel pipe. Pipes for hot water heating do not suffer seriously if the same water is circulated repeatedly, but the corrosion becomes rapid if much make-up water is added, especially in districts where the water is soft. In systems using open heaters where the water was allowed to come to rest at 180° F., or higher, thus discharging the gases, the pipes showed practically no corrosion in 10 years' service. In another system a storage tank filled with expanded steel lathing was used, practically all the free oxygen was removed in the tank, and in three years there was practically no corrosion in the pipes. The free CO_2 present is not removed by this treatment, hence it was concluded that the effect of CO_2 in such a system is negligible. In a steam heating system any non-condensable gases in the feed water are reabsorbed by the condensate and may cause serious corrosion, especially along the bottom of horizontal lines. The gases may be removed from the feed water by the use of open heaters, especially if assisted by a steel sheet. Air leakage in steam returns should be avoided as much as possible. Where exhaust steam is used a coating of oil usually forms on the inside of return pipes and protects them. Corrosion of the blades of a steam turbine was halted by adding heavy paraffin base oil to the steam head of the turbine. Further details as to protecting piping from the harmful effects of free oxygen will be found in Technical Paper 236, U. S. Bureau of Mines.

SAFE PRACTICE IN USING WIRE ROPE IN MINES.

By R. H. Kudlich and O. P. Hood.

THE essentials of good practice in the use of wire ropes in mining and the reasons underlying it are given in Technical Paper 237, U. S. Bureau of Mines. The statements in this are so condensed that they cannot be abstracted. The topics discussed are size of rope, material, construction of rope, lay of rope, length of rope. sheaves and drums, position of drums, idler sheaves and rollers, handling and storage of ropes, attachment of rope, renewal of rope-fastenings, safety chains, attachment of ropes on slopes, lubrication of ropes, inspection of hoisting ropes, rules for discarding ropes.

DANGEROUS AND SAFE PRACTICES IN BITUMINOUS COAL MINES.

By Edward Steidle.

THE use of photographs to illustrate safe and unsafe practices in bituminous coal mines was chosen as the basis of Miner's Circular 22, of the U. S. Bureau of Mines. The photographs were made in coöperation with the Ellsworth Collieries Co., Ellsworth, Pa., and the Consolidation Coal Co., Fairmont, W. Va. Some of the photographs show more than one bad or good practice. The pictorial method is considered to be the most effective one in appealing to miners, especially those who find difficulty in the use of the English language. In 1907, out of every 1000 employes in coal mines in the United States, 4.81 were killed, while in 1916 3.03 were killed, showing the effect of the campaign for safety in the mining industry which has been carried on by the Bureau of Mines.

Concrete Parts for Generators. C. M. HACKETT. (*General Electric Review,* vol. xxii, No. 10, p. 843, November, 1919.)—With our present knowledge of aggregates, cement, water and the methods of combining them it is possible to get not only uniform strength in all parts of a concrete structure of large size and mass, but also to produce duplicates of that structure in any quantity desired. This progress, combined with the great strength of the finished product, has led to the adoption of reinforced concrete for various classes of work where metal heretofore has been regarded as the only suitable material.

There are two parts of large size, in low speed vertical shaft electric generators of hydro-electric installations, that with advantage can be made of reinforced concrete, namely, the stator frame and thrust-bearing support. The use of concrete instead of metal for these parts does not involve any problems of stability or strength that cannot readily be solved by care in design and construction. Some of the large alternating current generators require stator frame and bearing support-castings of enormous size that tax manufacturing and shipping facilities. The economics to be found in the substitution of concrete for metal in these parts lie chiefly in the lower cost of materials and labor, reduction in shop expenses, and savings in freight and handling charges. It appears also practicable to build stator frames of concrete for large size horizontal shaft machines, using either a solid or split ring, as may be desired.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting held Wednesday, December 17, 1919.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 17, 1919.
PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to the membership since last report, 5.

Reports of progress were presented by the Committee on Library, and the Committee on Science and the Arts.

The following nominations were made for officers and managers to be voted for at the annual election to be held on January 21, 1920:

For President (to serve one year), Walton Clark.

For Vice-President (to serve three years), Coleman Sellers, Jr.; (to serve one year), Charles Day.

For Treasurer (to serve one year), Cyrus Borgner.

For Managers (to serve three years), Gellert Alleman, G. H. Clamer, Theobald F. Clark, Walton Forstall, Benjamin Franklin, Harry F. Keller, George D. Rosengarten, Wm. Chattin Wetherill; (to serve one year), Howard S. Graham, C. C. Tutwiler. The following members were appointed to act as tellers of the election: Messrs. W. N. Jennings, Henry F. Colvin, and Lucien E. Picolet.

The President then announced that the Philadelphia Association of Members of the American Society of Civil Engineers was meeting jointly with the Institute, and requested Mr. S. M. Swaab, President, to take the chair.

Brigadier General R. C. Marshall, Jr., was prevented from attending the meeting because of serious illness in his family, and his paper on "The Construction Division of the Army" was read by Colonel G. R. Solomon, Chief of the Engineering Branch of the Construction Division, U. S. Army, War Department, Washington, D. C. An account was given of the work of providing camps and cantonments in the various parts of the country for the citizen soldiery called to the Colors soon after the entry of the United States into the World War. In addition to housing accommodations for more than two million men, the Construction Division built arsenals, storage depots, industrial plants, gas plants, proving grounds, etc., for the Ordnance Department; hospitals with a capacity of more than one hundred and twenty-one thousand beds for the Medical Department; huge storage depots and port terminals at several points along the Atlantic Coast for the Quartermaster Department; warehouses and flying fields for the Signal Corps; mechanical repair shops for the Motor Transport Corps; and embarkation and debarkation facilities for the Transportation Service. The water supply for the various camps presented a serious problem,

and it was necessary to install 275 different water supply systems, involving the construction of 1100 miles of pipe, from 6 to 30 inches in diameter; 700 miles of service pipe, ¾ to 2 inches in diameter, with a combined pumping capacity of 650,000,000 gallons per day; filter plants were built having a capacity of 40,000,000 gallons. The construction projects undertaken for the Ordnance Department, embracing many new problems of construction and manufacture, plant layouts and shop arrangements were also described. There were 60 of these projects, costing a total of $175,000,000. The subject was illustrated by lantern slides, photographs, diagrams, plans and drawings, many of these being loaned by Lieutenant Colonel E. B. Morden, U. S. A., the Constructing Quartermaster, at Philadelphia, the officer in charge of the construction of the U. S. Army Supply Base at Greenwich Point, Philadelphia. A discussion followed the reading of the paper, in which Lieutenant Colonel Morden, Mr. Henderson, Mr. Penrose, and others participated. On the motion of Mr. Henderson, duly seconded, it was directed that the meeting express its regrets at the absence of General Marshall, and that its thanks be extended to Colonel Solomon.

Adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, December 3, 1919.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 3, 1919.

MR. BENJAMIN FRANKLIN *in the Chair.*

The following report was presented for final action:

No. 2713: Kemp Gas System. Edward Longstreth Medal of Merit awarded jointly to William Wallace Kemp and William H. Van Horn, both of Baltimore, Maryland.

The following reports were presented for first reading:

No. 2731: Hydrogenation of Oils.

No. 2740: Barker Wrenchless Chuck.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A joint meeting of the Section and the Philadelphia Section of the American Chemical Society was held in the Hall of the Institute on Thursday evening, November 13, 1919, at 8 o'clock. Mr. Samuel S. Sadtler, on behalf of the American Chemical Society, and Dr. Joseph S. Hepburn, on behalf of the Institute, presided jointly. The minutes of the previous meeting were approved.

E. V. McCollum, Ph.D., Professor of Bio-Chemistry in the School of Hygiene and Public Health of The Johns Hopkins University, Baltimore,

Md., delivered a lecture on "Nutrition and Physical Efficiency." A résumé was given of researches in nutrition conducted on animals during the past decade, with special reference to the etiology and correction of "deficiency diseases." The dietary habits of the lower animals and man in various geographical regions were reviewed in the light of this newer knowledge; and deductions were drawn concerning those diets which are most satisfactory for the promotion of physical vigor.

The paper was discussed; a rising vote of thanks was extended to Dr. McCollum, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Mining and Metallurgical Section.—A meeting of the Section was held on Thursday evening, December 4, 1919, at 8 o'clock. Mr. George R. Henderson in the chair. The paper of the evening on the "Destruction of French Coal Mines and Their Rehabilitation" was presented by Mr. George S. Rice, Chief Mining Engineer, Bureau of Mines, Department of the Interior, Washington, D. C.

It was shown that the destruction of the French coal mines in the Nord and Pas-de-Calais district was of two kinds, battle and systematic, systematic far exceeding the destruction incident to battle.

The collieries wrecked by the Germans produced, prior to the war, 20,000,000 tons of coal per annum. French engineers estimate that it will require five years, on an average, to place the mines on an operating basis and ten years to recover their normal output. The subject was illustrated by lantern slides from photographs taken by the lecturer, and from official photographs furnished by the French Government.

After a discussion of the paper by Messrs. Price, Penrose, the chairman and others, a vote of thanks was extended to the speaker, and the meeting adjourned.

ALFRED RIGLING,
Acting Secretary.

Section of Physics and Chemistry.—A meeting of the Section was held on Thursday evening, December 11th, at 8 o'clock, in the Hall of the Institute. Dr. Harry F. Keller in the chair. The minutes of the previous meeting were read and approved.

E. W. Dean, Ph.D., Petroleum Chemist, U. S. Bureau of Mines, Pittsburgh, Pa., delivered an illustrated lecture on "Motor Fuels." The manufacture of gasoline by straight distillation of crude oil, by the cracking process, and by recovery from natural gas was described. Statistics were given concerning the production, consumption, and marketing of gasoline. The modes of testing motor fuels and various substitutes for gasoline as a fuel were described.

The paper was discussed by Drs. Keller, Goodspeed and Dean, and Messrs. Tutwiler, Fulweiler and Hicks. On motion of Dr. Walter T. Taggart a vote of thanks was extended to Dr. Dean. The meeting then adjourned.

JOSEPH S. HEPBURN,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, December 10, 1919.)

RESIDENT.

DR. HIRAM S. LUKENS, Chemist, Harrison Laboratory, University of Pennsylvania, Thirty-fourth and Spruce Streets, Philadelphia, Pennsylvania.

NON-RESIDENT.

MR. JAMES D. LEE, in charge of Technical Publicity, Westinghouse Lamp Company, Bloomfield, New Jersey.

MR. W. I. OHMER, President, Recording and Computing Machines Co., Dayton, Ohio.

MR. LEWIS K. SILLCOX, Mechanical and Electrical Engineer, 169 Twenty-sixth Street, Milwaukee, Wisconsin.

DR. R. B. VON KLEINSMID, President, University of Arizona, Tucson, Arizona.

CHANGES OF ADDRESS.

MR. C. O. BILLOW, 416 West Grand Avenue, Chicago, Illinois.

DR. GEBHART BUMCKE, in care of National Oil Products Co., Essex and Front Streets, Harrison, New Jersey.

MR. JAMES H. DAWES, 3300 Arch Street, Philadelphia, Pennsylvania.

MR. J. M. DIVEN, Secretary, American Water Works Association, 153 West Seventy-first Street, New York City, New York.

MAJOR THOMAS H. GRIEST, 1631 Arch Street, Philadelphia, Pennsylvania.

MR. R. K. HONAMAN, Development and Research Department, American Telegraph & Telephone Company, 195 Broadway, New York City, New York.

MR. HUTTON KENNEDY, The Hero Manufacturing Co., Twenty-third and Westmoreland Streets, Philadelphia, Pennsylvania.

MR. WILFRED LEWIS, Rose Lane, Haverford, Pennsylvania.

MR. FRED J. MILLER, 319 West Ninety-fourth Street, New York City, New York.

MR. ALEX. E. REOCH, in care of The Radio Corporation of America, 233 Broadway, New York City, New York.

MR. F. W. SALMON, General Delivery, Mobile, Alabama.

MR. EDWARD A. STROUD, 508 South Forty-first Street, Philadelphia, Pennsylvania.

MR. PERCY WEDLAKE, 125 Atlantic Street, S.E., R.F.D. No. 8, Anacostia Station, Washington, District of Columbia.

MR. DAVID H. WILSON, JR., Wilson Welder and Metals Co., 2 Rector Street, New York City, New York.

NECROLOGY.

Mr. Hugh McCaffrey, 1711 North 4th Street, Philadelphia, Pa.

LIBRARY NOTES.

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JACOBS, F. B.—Abrasives and Abrasive Wheels. 1919.
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TURNEAURE, F. E., and MAURER, E. R.—Principles of Reinforced Concrete Construction. 1919.

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BOOK NOTICES.

THE ANALYSIS OF MINERALS AND ORES OF THE RARER ELEMENTS. FOR ANALYTICAL CHEMISTS AND ADVANCED STUDENTS. By W. R. Schoeller, Ph.D., and A. R. Powell. 234 pages, contents and indexes, 8vo. London, Chas. Griffin & Co.; Philadelphia, J. B. Lippincott Co. $5.00.

Interpreting the term "rarer" in a somewhat wider sense than that used in older chemistry, this work gives a valuable summary of the processes for over two dozen metals, ranging from such comparatively common ones as lithium, molybdenum and platinum, to the very rare cerium associates, and indium, gallium and radium. The improvement of methods of detection and separation, and the systematic search for these less common elements has brought to light many sources formerly unsuspected, and the special properties of some of them have brought them from brief allusions in text-books and reference works to important products of the industrial world and research laboratory.

As the authors state, only the rarest elements are yet without practical use, some supposed to be of very restricted occurrence have been found widely distributed, while others again have been of late years obtainable from local deposits of considerable extent.

The text-book methods of detection and separation of these elements belong in many cases to the science of fifty years or more ago, but the process of research in the hands of specialists, and the invention of new methods of investigation have brought about great changes, and it is the purpose of this volume to present the present-day procedures for the entire series. The book is packed with interesting and valuable information, much of which is presented in a condensed tabular form. The special methods of research, *e.g.*, spectroscopic and electroscopic, are described in detail, and it is interesting to note that the electroscope advised for radium determinations is taken from bulletin 104 of the United States Bureau of Mines. The metric system is used throughout, and the more advanced nomenclature for salts, although, as might be expected in a work of British provenance, the final "e" is retained in such words as "chloride." The ordinary unit of weight is written "grm." and cubic centimetre is abbreviated to c.c., both of which forms are commendable. In looking over the procedures, many of which are very complex, the thought occurs to the reviewer that before long, the optical methods now

attracting so much attention in mineralogy and organic chemistry will soon be applied to the field covered by this work, and give chemists valuable new methods of detecting and distinguishing between otherwise closely allied elements. Under thorium no reference is made to mesothorium, the importance of which would seem to justify at least a brief notice. Praseodymium and neodymium receive very brief notice also.

The book is excellently printed on good paper and the text is clear and carefully proof-read.

HENRY LEFFMANN.

NOTIONS FONDAMENTALES DE CHIMIE ORGANIQUE. By Charles Moureu, member of the Institute. Sixth edition, 552 pages, index and prefaces, 8vo. Paris, Gauthier-Villars, 1919. Price, 24 francs, net.

A previous edition of this work was reviewed in this journal a few years ago, but the present issue is larger by nearly fifty per cent. It is wholly a treatise on fundamental theories of the structure of organic bodies, practically no descriptive matter being given. A very large amount of information is furnished, and all the important theories are vividly and concisely presented. The printing and paper are of good quality; the type, though small, is easily read. The vast field of organic chemistry has been culled with judgment so as to compress within a convenient volume an introduction to the present-day theories that will be a guide to students and teachers. For the author's zeal and industry high praise must be given, but some features of the book require animadversion. The continued use by French chemists of the superiors instead of inferiors for the exponents in formulas has now no justification, and leads the reviewer to a suspicion that, as straws show which way the wind blows, some of the exceptional methods of French chemists indicate that if ever there is a league of nations, France will be a rather cantankerous member thereof. The equals sign is used always for reactions, instead of the arrow now generally preferred by chemists. The most serious of the infractions of the international rules is in the writing of the structural formulas of the cyclic compounds. The benzene hexagon is always written by our author with CH groups attached to the angles. Now Kekulé stated (*Ann. Chem. Pharm.*, 1866, v. cxxxvii, p. 129) that the plain hexagon stands for the whole molecule, C_6H_6, of benzene. This plan has been adopted by all careful writers in the field, and it is to be regretted that so excellent a work is marred by such a departure from a reasonable custom. Notice should also be made of such terms as "cétone" and "cétose." There seems to the reviewer to be no good reason for not using "k" as the initial in these words, for, though the letter itself is not an inherent member of the French alphabet, its sound is very frequent in the language and no person sufficiently educated to use this book can be unacquainted with the symbol and its pronunciation.

The work is very easy reading, very comprehensive and, in its presentation of the great theories of organic chemistry, up to date. An interesting summary is given on Gomberg's work on the so-called trivalent carbon.

HENRY LEFFMANN

THE PETROLEUM HANDBOOK. A practical reference book. By S. O. Andros, A.B., B.Sc., E.M. Chicago, Shaw Publishing Company, 16mo. Price, $2.00. net.

This compact and neatly printed pocket volume contains a large amount of interesting and important information on petroleum, a material now looming more than ever in the world's affairs, and not at all unlikely to become the principal cause of the next great war. The work is divided into eight chapters, covering the following subjects: "Natural History of Petroleum," "Exploration and Drilling," "Preparation for Market," "Natural Gas and Gasoline," "Shale Oil Production," "Marketing of Petroleum and Products," "Legal Regulations," "Economic Applications." The author states that this last chapter contains information not to be found in any other publication.

To the general reader one of the most interesting features is the graphic presentation of the world's production of petroleum and the proportion contributed from different nations. From this we find that in 1917, the United States contributed two-thirds of the total production and Russia stood next with nearly 14 per cent. The production from 1857 to 1917, both inclusive, was nearly 7,000,000,000 barrels of 42 gallons each (a little less than 936 million metric tons), of which nearly 61 per cent. came from the United States and a little over 26 per cent. from Russia. The importance of Russia in the present fuel situation is thus shown. For 1917 the approximate yield in the higher proportions are: United States, 66 per cent.; Russia, 13.6 per cent.; and Mexico, 10.9 per cent. The lower Russian yield is in all probability due to its disordered state. During 1917 the largest yields in the United States were from the Oklahoma and California fields.

HENRY LEFFMANN.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS. BULLETIN NO. 49. METERING CHARACTERISTICS OF CARBURETORS. 55 pages, illustrations, plates, tables, quarto. Washington, Government Printing Office, 1919.

This report, prepared by Percival S. Tice and H. C. Dickinson, of the Bureau of Standards, presents the results of investigations conducted for the Committee by the Bureau. A description is given of the carburetor testing-equipment constructed by the Bureau of Standards for the convenient and accurate observation of carburetor performances alone, unaffected by engine characteristics. This apparatus permits the testing of carburetors and their elements at widely varying air pressures and temperatures, for both steady and controlled pulsating flow. Fuel quantities are determined by weight and air quantities by an included orifice meter.

Results are given of experiments to determine the effects of varying the diameter, length, and form of entrance of metering passages, as well as of fluidity change with temperature. Under the title "Characteristics of Air Flow in Carburetors," the results of experimental dimensions of the coefficient discharge for various types of carburetor air metering passages are discussed. The next subject considered is the "Effect of Pulsating Air Flow in Carburetors," giving the results of experimental determinations of the effect of pulsating air flow upon the metering characteristics of two carburetors embodying widely different metering methods.

Part V is devoted to a discussion of the theoretical and experimental mixture proportioning characteristics of carburetors as applied to aircraft service, also of the mixture ratios for optimum engine performance. The altitude and throttle compensation characteristics experimentally determined for five carburetors are studied and a new type is shown which possesses nearly complete altimetric compensation. The concluding part of the pamphlet discusses means for securing correct altimetric and throttle compensation. Copies of this Bulletin may be obtained from the Committee.

PUBLICATIONS RECEIVED.

Robison's Manual of Radio Telegraphy and Telephony for the Use of Naval Electricians, by Captain S. S. Robison, U. S. Navy; revised by Captain D. W. Todd, U. S. Navy, and Commander S. C. Hooper, U. S. Navy. 5th edition, revised. 307 pages, illustrations, plates, diagrams, 8vo. Annapolis, Maryland, United States Naval Institute, 1919. Price, $1.50.

Notions Fondamentales de Chimie Organique, par Charles Moureu. 6me edition, revue et considérablement augmentee. 552 pages, 8vo. Paris, Gauthiers-Villars et Cie, 1919. Price, 24 francs.

The Petroleum Handbook, by Stephen O. Andros. 206 pages, illustrations, 16mo. Chicago, Shaw Publishing Company, 1919. Price, $2.00.

U. S. Bureau of Mines: Bulletin 181, Law Serial 19. Abstract of current decisions on mines and mining reported from January to May, 1919, by J. W. Thompson. 175 pages, 8vo. Technical paper 211, approximate quantitative microscopy of pulverized ores, by Will H. Coghill and J. P. Bonardi. 20 pages illustrations, plates, 8vo. Washington, Government Printing Office, 1919.

Statement of Mr. S. A. Thompson, Secretary and Treasurer, National Rivers and Harbors Congress, Washington, D. C. Extracts from hearings before the Committee on Interstate and Foreign Commerce of the House of Representatives, 66th Congress, first session on H. R. 4378. 16 pages, 8vo. Washington, Government Printing Office, 1919.

Patent Policy of a Public Laboratory, by William D. Shoemaker. Reprinted from the Journal of the Patent Office Society for November, 1919. 16 pages, 8vo. Washington, 1919.

Carbo-Coal. ANON. (*Steam*, vol. xxiii, No. 3, p. 62, September, 1919.)—By a new process of low temperature distillation, bituminous coal is treated in such a manner as to recover great quantities of valuable by-products, such as toluol, sulphate of ammonia and valuable oils. From the residue is made a valuable smokeless fuel, of the form of briquettes. Tests of "Carbo-coal" by the Navy disclose that it contains less than 4 per cent. volatile matter, rendering it practically smokeless. Moreover, it is found to work satisfactorily where there is limited grate area and restricted boiler capacity.

R.

CURRENT TOPICS.

New Method of Dehydrating Food. (*Am. Chem. Soc., News Service* No. 249.)—Meats, eggs, vegetables and fruits can now be dried in a manner which preserves their original properties and nutritive value and still have an appearance of freshness when prepared for the table. Although in former years there were dried fruits and vegetables that had a fine appearance, it was often found that they had been treated with sulfites and other materials, the use of which had been questioned by food experts.

Dr. K. George Falk, of the Harriman Research Laboratory, Roosevelt Hospital, New York, N. Y., explained the new methods in an address before the New York Section of the American Chemical Society, of which he is a member. He announced that, following the experimental stage in this process, meats and vegetables had been thoroughly dried in the Industrial Chemistry Laboratory of Columbia University under the supervision of Professor Ralph H. McKee and had been shipped to different parts of the world, where they have been used with success. One consignment of the meat dried in this manner gave great satisfaction in Armenia, where it was distributed by the Near East Relief Fund. Other products of the new dehydration process had been taken to distant parts of the world by exploring parties and had been found to answer all the requirements.

Dr. Falk said that from these meats and other foods which were dried in a vacuum delicious dishes could be made, the taste of which would commend them to any housewife. From the dried meat, savory stews and hashes are made, while the vegetables which may be incorporated with the meat have as fine a flavor as if they had only recently come from the garden.

It would be possible by means of this process to dry beef in vacuum ovens in parts of the earth where cattle may be raised very cheaply, as in Argentina, and to transport the dried product for many thousands of miles at very low freight cost. As canned fruits contain considerable moisture and are placed in metal containers, the advantages of the vacuum-dried products become manifest, according to the view of Dr. Falk.

"Transportation," said he, "has always been a question of vital importance. Ships and other common carriers are always at a premium and again certain kinds of food require special equipment, such as cold storage. For example, the plentiful supply of sheep in New Zealand might benefit the rest of the world to a greater extent if more transportation facilities were available."

Dr. Falk said that usually sun-dried meats and other foods were

discolored and that their nutritive values were impaired. While even with fairly good methods of dehydration it would have been found necessary to use bleaching agents, a recourse which was not required, according to the process developed at the Harriman laboratories. The incentive to develop this method of preservation for food products was given early in November, 1917, by Colonel John R. Murlin, in charge of the Division of Food and Nutrition of the U. S. Army, and was developed by Dr. Falk, Dr. Edward M. Frankel and Professor Ralph H. McKee.

"In the dehydration of meats," said Dr. Falk, "the temperature must be kept below the point at which the proteins coagulate, for if there is too low a temperature the process of dehydration will be unnecessarily prolonged, with the result that often spoilage will occur and the overhead cost will be greatly increased. It is possible to solve this problem of dehydration by the use of a suitable vacuum drier in which the meat or other food product is introduced, in pieces of suitable size, and kept in the vacuum at a temperature which is below that of cooking or which makes no appreciable change."

Dr. Falk said that a large variety of foods had been dehydrated by the vacuum method and that a number of others will probably be subjected in time to the same process. The mechanism used is not complicated and can be easily installed at remote places.

"In considering food preservation methods in general, it may be stated," he said, "that such methods will come into use more and more." The Government estimated that 50 per cent. of the fruits and vegetables grown in this country never reach the consumer as a result of poor transportation facilities, irregularities in marketing or other causes. At the same time, greatly because of recent work on such questions as food hormones, the tendency is to use fresh foods wherever possible. The newer dehydration processes approach more nearly the requisite standards of fresh foods than do the older methods of preservation. The whole question is in a state of development. Dehydration offers the most promising outlook for the future. Air dehydration marks a great advance over the older methods of food preservation, and it would appear that vacuum dehydration possesses in its turn advantages over air dehydration.

Fixed Oils Production in the United States.—The fatty oils are indispensable both in food supply and in many manufacturing industries. They have been the main source of glycerol, which is so important in the explosives industry, though recently it has been shown that the fermentation of carbohydrates yield as a by-product notable quantities. The subject is discussed in Bulletin 769 of the U. S. Department of Agriculture, recently issued. The sum total of the world's supply of fats and oils is less than that of either of the other two types of foods (carbohydrates and proteins), hence a sudden drain is quickly noticed. A great war creates such a drain, since ten tons of fat are required for the

production of one ton of glycerol. The fatty acids, which are the other product, have no food value, but are useful for the manufacture of soap. In England, at the outbreak of the European war, glycerol rose quickly from $250 to $1250 a ton.

In the United States, the use of vegetable oils is increasing. This is due partly to the application of processes for making hard fats from the liquid ones by hydrogenation, and partly to the extending use of the vegetable oils as a substitute for butter. At the outbreak of the war in 1914, Germany was probably the worst prepared country in regard to supply of fats and oils. Preparing, as the nation had been along many lines for self-sustaining, it had overlooked this particular supply, and probably the British blockade hit the enemy harder in this line than in most others. This fact calls attention to the importance of a nation developing its oil supply, and this can be done only through agricultural activity.

In normal times, the United States produces nearly 4,000,000,000 pounds of fats and oils, exclusive of butter-fat, imports over 300,000,000 pounds, exports about 1,000,000,000 pounds and consumes nearly 3,500,000,000 pounds. Including the fat in the butter and cheese made in this country, the total production of fats and oils is about 30,000,000 tons.

H. L.

Fighting Forest Fires by Bombs Impractical. (*U. S. Department of Agriculture, Office of Information.*)—Ingenious persons have recently proposed as a method of fighting forest fires that gas bombs be dropped from airplanes. Officials of the Forest Service say that this suggestion is entirely impractical. There is no analogy between the suggested method and the use of poison gas bombs in fighting, because a fire can not be "poisoned" but must be smothered. Although one part of a poison gas to one million parts of air might be sufficient to kill soldiers, yet 750,000 parts of inert gas to a million parts of air probably would not suffice to put out a fire.

The only kind of a gas which will assist in stopping a fire is an inert one that will neither burn nor support combustion, such as nitrogen or carbon dioxide.

From the standpoint of cheapness and ease in handling, carbon dioxide would probably be the most promising gas, were gas bombs to be experimented with in forest fire fighting. However, as soon as an attempt is made to work out practical plans for such an undertaking, difficulties become apparent. If an airplane carrying 500 pounds of gas bombs containing 300 pounds of carbon dioxide succeeded in dropping the bombs *exactly* on a fire covering some 700 square feet, and if the gas liberated did not escape outside this area or rise more than 10 feet above the ground, such an attack would still be far from effective. The 300

pounds of gas would be equal, in volume, to about 3000 cubic feet, and so the atmosphere surrounding the fire would be about 43 per cent. carbon dioxide and 57 per cent. ordinary air. Since the air contains 21 per cent. oxygen, this mixture would contain 21 per cent. of 57 or 12 per cent. oxygen—enough to support combustion. From such facts Forest Service officials believe that effective use of gas bombs for fire fighting in forests is entirely out of the question.

Work of the United States Bureau of Chemistry for the Last Fiscal Year.—A preliminary report has been issued by this bureau, giving some of the more important work done during the year ending June 30, 1919. The research department was considerably crippled by the assignment of many of its workers to war industries laboratories, but notwithstanding, more prosecutions were brought than in any previous year, and the number of publications by the bureau has also exceeded previous records.

Among the food and drug adulterations that came to notice are enumerated: Slack-filled cans, rotten eggs, fake egg substitutes, butter with excess water, common glue sold as gelatin, adulterated olive oil, frozen oranges, excess of water in canned tomatoes, cacao adulterated with cacao shells. In all 1052 seizures and 843 criminal prosecutions were brought. Of 1019 cases of all kinds reported to the department as terminated in the courts, only three were decided against the government. One line of investigation which occupied much of the time of the inspection force of the bureau was the examination of canned salmon, which included testing the extensive stocks held by the government before allowing it to be sold to the public at large. Much attention has been given to improving the manner of packing and transporting the more perishable foods, in connection with which it has been found that the use of 100-pound boxes for fish is much better than the customary use of barrels. Material improvement in the classification, handling and packing of eggs has been attained. The breakage in railroad transportation has been reduced.

Methods of preserving food so as to carry over a plentiful supply into a period of scarcity has been closely studied, especially the methods of drying vegetables which promises well. A valuable service was rendered in furnishing sugar substitutes for use in the manufacture of soft drinks, and some of these substitutes have proved of such merit that they will probably remain in use.

The prevention of dust explosions in grain elevators and flour mills has been given much study and a marked reduction in this class of disasters has been attained. The bureau reports that corn-cobs, one of the largest waste products of farming, may now be utilized for the preparation of adhesive gum, and a rare sugar, xylose, and processes for converting this into useful mate-

rial have been patented and published. Cull oranges and lemons, not suitable for marketing as fresh fruit, have been made to yield several valuable products, among which are citric acid and marmalade. Work to improve existing methods of extracting starch from cull and surplus potatoes is under way. The influence of the prohibition movement seems to have stimulated the manufacture of barley-sugar or maltose and maltose syrup, and practical studies of the means of using maltose syrup in candy making have been taken up with encouraging results so far.

Many investigations in aid of standard industries have also been carried out. The complete report will be awaited with interest.

H. L.

A Rock-crystal Lens. H. D'A. POWER. (*Camera Craft,* vol. xxvi, No. 11, p. 421, November, 1919.)—Some years ago I had occasion to take a few portraits indoors, exposures that I wished to make instantaneous, and if possible, without the knowledge of the subject. I naturally thought of using one of the modern lenses working at f/3.6 or f/4, but as I already had a Protar working at f/5.6, I did not relish the prospect of expending the very large sum that the larger apertured lens would demand. Just about that time some work had been done in determining the quality of pictures yielded by infra-red and ultra-violet rays; the latter precluding the use of glass through which these rays of great actinic power cannot pass. The concurrence of these two facts suggested the possibility of using a quartz spectacle lens, mounted so as to permit of a very large aperture. By chance I was able to obtain a five-inch spectacle lens of this type with a diameter of one and a quarter inches, this making an aperture of f/4 practically possible. This was fixed in a temporary mount and the first experiment was a satisfactory portrait made in my office with an f/4 stop, and an exposure of one-sixteenth of a second. The subject was placed at least ten feet from a rather high window, and the lighting was that of an average afternoon. Other experiments followed with equally good results, both in portraiture and landscape.

Having unfortunately lost the lens, a second one only produced pictures that were marred by greatly inferior definition. I later found that crystal or pebble lenses, as they are called in the trade, had passed out of use on account of the frequency of structural defects in the material. But recently on attending a meeting of the State Medical Society, I was shown a number of very beautifully made crystal lenses used in the transmission of violet rays for therapeutical purposes. I inquired of the agent, representing the Hanovia Chemical and Manufacturing Company of Newark, New Jersey, as to whether or not a spectacle lens could be made for me that would be structurally flawless and was assured that it could be done. In due time a four and a half-

inch focus lens with an aperture of one and one-half inches came to hand. The results obtained by this lens were most satisfactory and it seems to me there is much to be said in favor of a very general use of lenses of this type.

It will be recollected by photographers of artistic tendencies that some years ago Major Puyo and other members of the Paris Photo Club started a movement for the use of spectacle lenses of large size, claiming for them the production of better balanced images, devoid of the harshness of the anastigmat and therefore having a plasticity of modeling that is absent from most photographs. It is an outgrowth of this movement that has given us the soft focus lens that is now so much in favor, but the good soft focus lens is a costly apparatus; ordinary spectacle lenses or, to use the correct term, simple non-achromatic lenses, have certain good and bad points. Among the former the ability to transmit a larger amount of light, owing to the absence of reflection from many surfaces, and great cheapness. Against these are to be placed linear distortion, which makes straight lines near the edges of the plate appear curved, and difference of focus between the image seen and the image recorded on the plate, which last can be overcome only by racking back after focusing.

When, however, a simple lens is made of rock crystal, this graver defect is so reduced as to be of no importance, for, whereas the difference between the visual and actinic of a glass lens is as much as one-fortieth of the focal length, the difference in the case of the rock-crystal lens is less than one-four hundredth, and this is insufficient to make any real difference in focusing necessary. The form of the lens should be that of a meniscus with the convex surface turned toward the plate. The diaphragm should be placed well in advance of the lens at a distance of about one-fourth of the focal length and a lens shade should be employed, practically when working at full aperture.

Humanity of Poisonous Gas. LIEUT. COL. AMOS A. FRIES, Corps of Engineers, Chemical Warfare Service, U. S. Army, formerly Brig. Gen. and Chief of the Chemical Warfare Service in the American Expeditionary Forces, France. (*Chemical Warfare*, vol. i, Nos. 11 and 12, 1919.)—The first gas attack was made by the Germans at Ypres with chlorine in 1915; the resulting death-rate was probably 35 per cent. During the last year of the war the death-rate from gassing fell to 2.5 per cent. in the British army, despite an enormous increase in the number of gas casualties—cases of gassing requiring medical treatment. Thus the number of gas casualties per month increased during the last sixteen months of the war to 14 times the number during the preceding year. The reduction in the death-rate was due to development of masks and other methods of protection. The statistics of the Surgeon General's office, U. S. Army, covering all cases of battle

casualties reported up to September 1, 1919, show that 23.4 per cent. of all casualties from bullets and high explosives and 1.87 per cent. of all casualties from gas resulted in death. Often a man injured by gas had 12 times as many chances of recovery as had one wounded by bullets or high explosives. Gassing did not predispose to tuberculosis nor open up old tubercular lesions. The death-rate is reduced solely by the gas-mask and training in its use. As new gases are introduced, the mask must be improved to protect against them.

Experiments with poison gases can be carried out with perfect safety in the laboratory, and on a large scale in the open. Light winds carry away all poison gases except mustard gas almost instantly in the open. While gases persist longest in woods at night in warm weather, yet they become so diffused that they are no longer dangerous after four to six hours; this period is reduced to one or two hours by wind and sunshine. Mustard gas may give off poisonous vapor for two days in warm dry weather, and for possibly two weeks in cold damp weather; but the vapor is carried only a short distance by the wind. Poisonous gases may be kept in suitable containers, including shells, for at least a year.

Irritating gases irritate the nose and throat. Lachrymatory gases produce a flow of tears. Both types of gas require wearing of a gas-mask when present in concentrations of 1 in 10,000,000, and thereby reduce the efficiency of combatant troops by 25 to 75 per cent. Gas is an excellent means of eradicating snipers. Cloud gas and that fired from mortars and projectors has a short range, about 1.5 miles. Beyond that range, the gas was fired in artillery shells. Gas warfare is humane and a great insurance to the safety of the United States.

J. S. H.

Graphite Production.—*Bull. 10, U. S. Geol. Sur.*, compiled by H. G. FERGUSON, gives information as to the amount of graphite mined in the United States during 1918. The material occurs in nature in two forms, crystalline and amorphous and each form has its special uses. The term "crystalline" or "flake" graphite is generally understood to mean specimens in which the crystalline nature is visible to the unassisted eye, and, of course, much of the so-called "amorphous" material will show crystals under the microscope. Crystalline graphite occurs in veins or distributed in flakes through the rocks; amorphous graphite may occur wherever coal or other carbonaceous deposits have been altered by the action of igneous rocks or movements within the earth's crust.

The bulletin separates the production of the two forms. The total production of crystalline graphite in 1918 was nearly 6500 short tons valued at about $225 per ton; the production of amor-

phous graphite in the same period was about the same in quantity, but the value was much less. The bulk of the crystalline graphite came from three states: Alabama, which yielded about 60 per cent.; New York, which yielded nearly 30 per cent., and Pennsylvania, about 10 per cent.

Artificial graphite, now a well-known product, is manufactured principally by the Acheson Graphite Company from power at Niagara. The output has increased greatly in recent years, and now forms an important item in the domestic supply. It is suitable for all the purposes of the natural graphite except the manufacture of large crucibles, but, on the other hand, it is more suitable for the manufacture of electrodes which are in great demand and which are not now made from the natural mineral. The production of artificial graphite for purposes in which it competes with the natural material, by the Acheson Company, rose from about five million pounds in 1915 to nearly ten million and a half in 1917. and was somewhat over nine million pounds in 1918. A small quantity of high-grade graphite has been obtained by H. Schmehl, at Chester Springs, Pa., from old crucibles.

H. L.

Trinitrotoluene Poisoning.—The extensive use of this explosive, commonly termed T.N.T., has drawn attention to its sanitary relations. It is, as might be expected, highly poisonous, whether taken directly or inhaled as dust. An investigation conducted by Messrs. Voegtlin, Hooper and Johnson, of the Hygienic Laboratory of the U. S. P. H. S. is published as Reprint 534 of that department. It was found that different species of animals exhibit marked differences in susceptibility to the substance. Dogs and cats (probably also human beings) are much more susceptible than white rats, guinea-pigs, and rabbits. The symptoms generally presented are cyanosis, bowel disturbance, jaundice and anæmia. The condition is not constant, as cyanosis, which usually appears at the beginning of the poisoning may disappear later. While true immunity is not developed, it appears that dogs (which were mostly used in the experiments) do not suffer such severe symptoms in the later stages of the poisoning. The poison is principally eliminated through the kidneys, but not in unchanged form. Dogs fed on meat seem to have a greater resistance to the substance than when given only white bread and milk.

Several methods of protection for workmen were tried. It was found that a varnish composed of 1 part shellac, 1 part of castor oil, and 24 parts of 95 per cent. alcohol could be used with satisfaction, as when applied to the skin of the hands and arms it dries to a protective film that does not peel off but can readily be removed by alcohol. A modification of this formula has been used for impregnating cotton gloves, by which they are rendered

efficient protectors. At the suggestion of Dr. Alice Hamilton, a number of solvents were tested to determine their capacity to remove the poison from the skin. It was found that a 10 per cent. solution of sodium hydrosulphite is the best of those tried; the next best is sodium sulphite solution. It appears that a certain percentage of workers are abnormally susceptible, due generally to a very permeable skin. These should be eliminated from the factory. The skin penetration is the most usual method of introduction of the poison, hence skin protection is especially enjoined, but inhalation is also not to be overlooked, and this must be met by free ventilation. The American investigators, however, did not find skin absorption to be as promising a method of infection as did the British investigators. A decrease of hæmoglobin is noticed early in the poisoning, and the investigators recommend a supervision over the workers by means of blood tests. It would seem that some simple form of gas-mask could be used to control the inhalation danger.

H. L.

Coal Mining Fatalities in the United States.—That coal mining is one of the most important industries of this country has been brought home to every citizen during the past few years. The amount of coal produced now approaches closely to 700,000,000 tons yearly, employing about 760,000 men. That it is a laborious and dangerous occupation is well established by the statistics of death and injury published from time to time. A bulletin prepared by A. H. Fay has just been issued by the Bureau of Mines, giving the fatalities in the coal mines of the United States during 1918. This was a year of somewhat abnormal conditions. The demand for coal was much increased over that of previous years, many of the expert miners and supervisors had enlisted or entered into more profitable industries, and a not inconsiderable number were drafted. This naturally made for a greater proportion of accidents as many comparatively inexpert men were employed, but, on the other hand, the more continuous operation of the mines prevented accumulation of gases and in some other ways improved conditions as compared with mines operated only part time. The total fatalities reported, including all fuel mining during the year was 2579. The non-fatal injuries are not given in the bulletin, but taking Pennsylvania statistics as a guide, it may be estimated that these amount to at least three times the fatal accidents, so that the total for the United States will be about ten thousand casualties for the year. There is still to be counted as part of the perils of the industry the disease and debilitation produced, especially the liability to tuberculosis, and in some mines to hook-worm. No data on these points are at hand and no estimate can be made, but there is little doubt that the morbidity percentage will be fairly high. Pennsylvania being the

only state in which any considerable anthracite mining is carried on, it is interesting to note that in 1916 the fatalities and non-fatal accidents in that industry were much higher than in the bitumionus mines of the state. The figures show that 1 life was lost for 155,000 tons of anthracite mined, and 1 life for 388,000 tons of bituminous coal. The non-fatal accidents were also of higher ratio in the hard coal mines. Part of this difference may be due to the depth at which anthracite is now generally mined. In Pennsylvania in 1916 the fatalities left 631 widows and 1510 orphans. Taking the United States at large for 1918 the production of coal of all kinds per life lost was 266,000 tons, an improvement over 1917, in which the production per fatality was 241,000 tons. The days worked in 1917 were 251, and somewhat higher in 1918.

H. L.

Manganese in New Mexico. (*U. S. Geol. Sur. Bull. 710-B.*)—This bulletin, prepared by E. L. Jones, Jr., presents the data in regard to the efforts made during the war to secure manganese from the New Mexico deposits. These are scattered mostly along the Rio Grande, west of the central line of the state, and occur in both sedimentary and igneous rocks. Both oxides and primary minerals are found but only the former are mined. A limited use of the ores has been made for many years, but the great increase in price of manganese brought about by the war, led to much more extensive operation of known mines and active search for new deposits. The total production to December 1, 1918, was 5500 tons. A few deposits are capable of yielding several thousand tons, but most are of small size. The ore has to be shipped to points east of the Mississippi, which involves a high freight rate. The minimum rate to Chicago was $8 per short ton, in addition to which the charges for mining and wagon transportation to the railroad siding were high, so that even with the high prices prevailing during 1918, little profit was made, and with return of pre-war prices, probably none of the deposits can be worked profitably.

H. L.

Gold-lode Mining in Alaska. (*U. S. Geol. Surv., Press Bulletin,* November, 1919.)—Twenty-five gold-lode mines were operated in Alaska in 1918, according to the U. S. Geological Survey, Department of the Interior. There was also a production from seven prospects—abandoned mines or small mines that were not in regular operation. The value of the lode-gold output decreased from $4,581,453 in 1917 to $3,473,317 in 1918, owing partly to the disaster at the Treadwell mine in April, 1917, and partly to curtailment of operations, especially in the Juneau district, because of shortage of labor. Southeastern Alaska, especially the Juneau district, is still the only centre of large quartz-mining operations in the territory. Next in importance is the Willow Creek lode

district. The production in the Fairbanks district decreased materially, as the lode-mine owners of Fairbanks are still awaiting the cheapening of operating costs, especially of fuel, which is expected on the completion of the Government railroad. In 1918 the average value of the gold and silver contents for all siliceous ores mined was $1.70 a ton; the average for 1917 was $1.37 a ton. These averages reflect the dominance in the total lode production of the large tonnage produced from the low-grade ores of the Juneau district.

Studies in Catalysis.—From pamphlets issued as reports of a symposium on catalysis, held at the thirty-sixth general meeting (September, 1919) of the American Electro-Chemical Society, some very interesting data are taken. The word "catalysis" was coined by Berzelius in 1836, but one of the most striking instances of the effect had been made known by Doebereiner four years previously, namely, the effect of manganese dioxide in promoting the decomposition of potassium chlorate. The subject of catalysis in the inorganic field has become of great importance of late years, owing to valuable applications in industries, such as the manufacture of sulphuric acid, ammonia and the hydrogenation of oils. One of the contributors to the symposium, Hugh S. Taylor, states that a striking physical feature common to the catalysis agents is that they are mainly porous or finely divided materials. For example, bog iron ore, a light porous ferric hydrate, is an agent in the oxidation of hydrogen sulphide to sulphur in purifying illuminating gas. Cuprous chloride distributed over a porous mass, such as fire-brick, is used in the Deacon chlorine recovery process. Platinum deposited on asbestos or magnesium sulphate, is used in the sulphuric acid manufacture. Porous, reduced, iron-molybdenum is used in ammonia synthesis, the massive alloy is inert. Porous bodies have, as a rule, high adsorptive powers, but the two properties are not necessarily correlative. Patrick, of Johns Hopkins, has found that a silica gel that he prepared is highly adsorptive, but not so far as known, catalytic. Taylor passes on to the consideration of the so-called "poisons" of catalysts, that is, the substances which in small amount deprive the catalyst of activity. His investigations lead him to the view that the effect is due to a slowing down of the velocity of the adsorption of the reacting substances. The value, therefore, of the clean surface is evident. Experiments have recently shown that "clean" charcoals are much more efficient in the gas-mask. One actual measurement of relative action has been made by Dr. Harned (U. of Pa.), who obtained contrasting results from two portions of charcoal, one of which had been cleaned by successive washings with chlor-picrin and the other simply evacuated. Curves plotted from the data show that the adsorption by the clean charcoal was much more rapid than with the uncleaned sample, but that it is evident that in an indefinitely long interval the effect of

both adsorbents will be equal. In the first five-minute intervals in an experiment, the adsorption of the cleaned charcoal was 500 times greater than with the uncleaned, it may be assumed that in a still briefer interval the difference will be much greater.

A further interesting feature is that admixture of small amounts of substances, perhaps not in themselves catalytic, will activate strongly a true catalyst. The action of the small amount of cerium oxide on thorium oxide in the gas mantle is well known, and it is found that a mixture of 0.5 per cent. of cerium dioxide with iron oxide gives a catalyst many times more reactive than the iron oxide alone. The term "promoters" has been given to substances of this activating class, but although a large amount of investigation has been given to the topic, the nature of the action is unknown. Undoubtedly, most valuable practical results will flow from extended researches in this line.

H. L.

Fog Signal System. ANON. (*The Marine Review,* vol. l, No. 1, p. 17, January, 1920.)—In coöperation with the Bureau of Lighthouses, experiments are being carried on by the Bureau of Standards to establish a radio fog signaling system. Such a system, when perfected, will give the navigator a reliable signal under any conditions of fog and make him independent of the lighthouse lamp. The principal object to be sought is the sending out of a radio signal automatically from a lighthouse and the reception of this signal upon a ship by a simple radio direction finder. If a number of important lighthouses on the Atlantic coast are equipped with this system, the safety of navigation will be greatly advanced. In connection with these experiments, radio transmitting apparatus is being placed at three lighthouses in Chesapeake Bay and the radio receiving apparatus and direction finder installed on a lighthouse tender. Three lighthouses are used, so as to give comparative information on different types of modern transmitting equipment and to determine which is the best suited for this work. The apparatus is of special type developed by the Bureau as a result of some of its researches on radio problems during the war.

R.

A 24-Hour Clock at Waterloo Station, London. ANON. (*Railway Age,* vol. lxvii, No. 24, p. 1171, December 12, 1919.)—Considerable interest is now being taken in England in the idea of timing trains on the 24-hour system. This method is general on the Continent, and is regarded as having the important advantage of rendering more clear the actual arrival and departure time of trains. Difficulties with regard to A.M. and P.M. are altogether surmounted, and on long-distance bookings it is a very simple matter to ascertain whether one will get to any point during the day or in the night. With this in mind, a 24-hour clock has recently been installed at

the Waterloo station of the London and Southwestern Railway, London, with a view to putting English "timings" into line with Continental. The clock has the usual dial with Roman numerals, the figures 13 to 24 being placed in smaller Arabic numerals inside, opposite their respective Roman numerals. Most of the time-tables of Continental bookings printed in England now use the 24-hour system.

R.

New Bearing Metal. ANON. (*Machinery,* vol. xxvi, No. 4, p. 329, December, 1919.)—A development in bearing metal which is the outgrowth of the scarcity of tin during the war was of great value to the Government during the period of hostilities. It is an electrically hardened lead with a very small percentage of other ingredients added which had never before been used in bearing metals. The Bureau of Standards made a series of tests on this new bearing metal and issued a report showing that the tensile strength of the metal is 13,000 pounds, the elastic limit 11,525 pounds, and that it is capable of enduring a running test at a pressure of 1000 pounds per square inch at a speed of 400 revolutions per minute. The final temperature was only 150 degrees F. The report stated that this metal possesses all the requisites of a good bearing metal, that is, hardness, compressive strength, low friction, and heat resistance, as well as low cost.

R.

Gas-Masks for Industrial Use. ANON. (*The India Rubber World,* vol. lxi, No. 2, p. 103, November 1, 1919.)—The gas-mask is rapidly finding its proper place in the industries. Experience has shown that it has a wide application in protecting workmen from the noxious gases and fumes given off in many chemical operations. In rubber factories gas-masks could be used around volatile solvents, such as carbon disulphide, carbon tetrachloride, sulphur chloride and certain organic accelerators. In allied chemical plants they give good protection in pyrite smelting and roasting operations wherever sulphur dioxide or oxides of nitrogen are encountered. The war gave great impetus to the development of better gas-masks, and now the Bureau of Mines has established a gas-mask department at the Pittsburgh Experiment Station, where masks of the army type will be developed for industrial use.

R.

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SOUND-RANGING.*

BY

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In the autumn of 1914 the French first undertook experiments to determine whether the enemy artillery positions could be located by means of the sound of the firing of the guns. These experiments met with sufficient success to warrant the establishment of sound-ranging sections along the entire western front. When the British arrived in force in France they also established a sound-ranging service which employed apparatus which was somewhat more elaborate than that adopted by the French and which was especially designed to meet conditions on a very active front.

When, in the early opening of 1917, the first American troops went into the line American sound-ranging sections went in with them, equipped with apparatus furnished by the British and directed by officers who had been trained in their special duties on the British front. At the same time other American sound-ranging troops were being trained in the back area and apparatus was being constructed in America with which to provide the sections which were needed when the steady flow of American combat troops began to arrive in France.

* Presented at a meeting of the Section of Physics and Chemistry held Thursday, October 23, 1919.

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At the signing of the armistice a battalion of ranging troops consisting of five companies was in France; about one-half of the battalion was engaged in sound-ranging and the other half in the special form of visual observation known as flash-ranging.

PRINCIPLES OF SOUND-RANGING.

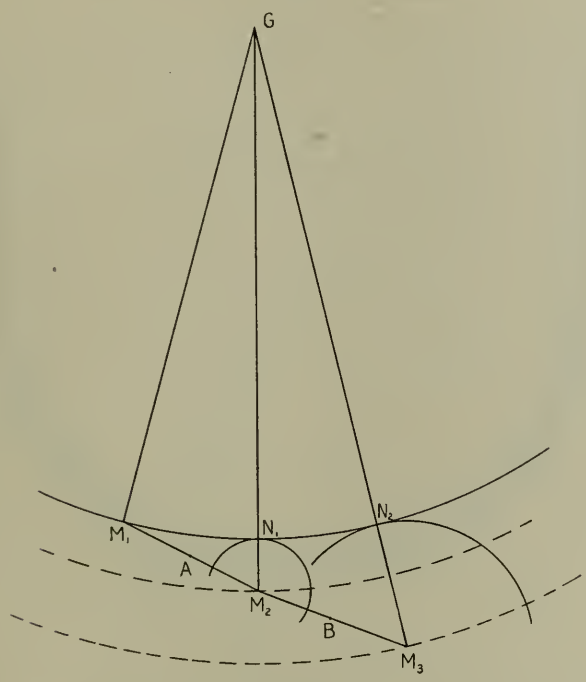
Sound travels in still air at zero degrees centigrade (the freezing point of water), at the rate of 330.6 metres per second (roughly 1100 feet per second). At 10 degrees centigrade the speed to the nearest whole number is 337 metres per second. The velocity is not only affected by the temperature of the air, but also the *apparent* velocity is very markedly affected by the velocity and direction of the wind. It follows from this that a survey carried out by the means of sound waves unlike a survey carried out in the ordinary manner by light waves is subject to errors introduced by the lack of accurate knowledge of the wind and temperature corrections which it is necessary to apply to the data of observation. Furthermore there is a lack of parallelism between a light survey and a sound survey which will be evident from the following consideration: To locate a point on the ground by a light survey it is only necessary to secure an intersection of two light streams towards two known points on a surveyed base line by the use of relatively small telescopes, while to obtain a location at all comparable in accuracy by means of sound it would be necessary to use instruments of prohibitively great size. Fortunately, however, advantage may be taken of the low velocity of sound compared to that of light to obtain a survey from *three* points without the use of listening apparatus of great size. This method entails the accurate measurement of the *differences* of times of arrival of sound at the three points. This, of course, entails the use of some form of accurate clock, and precludes the use of human observers who might differ too much in their reaction times.

In still air at 10 degrees centigrade the sound from a gun moves out in a wave of compression and rarefaction which travels 337 metres per second. If the gun is at G and mechanical listeners electrically connected to a common timing device are situated at M_1, M_2 and M_3 and if, for example, GM_1 be 3370 metres, the sound of the gun will reach M_1 in 10 seconds, and the front of the spherican wave will go through M_1, N_2 and N_3. This wave front moving with the velocity of 337 metres per second will reach M_2

later than it reaches M_1. How much later is determined by the time it takes the sound to travel the distance N_1, M_2.

Thus the interval between the arrival of the sound at M_1 and at M_2 will be $\frac{N_1 M_2}{337}$ seconds, and the interval between the arrival at M_1 and at M_3 will be $\frac{N_2 M_3}{337}$ seconds. Suppose the distance $N_1 M_2$ were 33·7 metres, then the interval of time between the arrival at

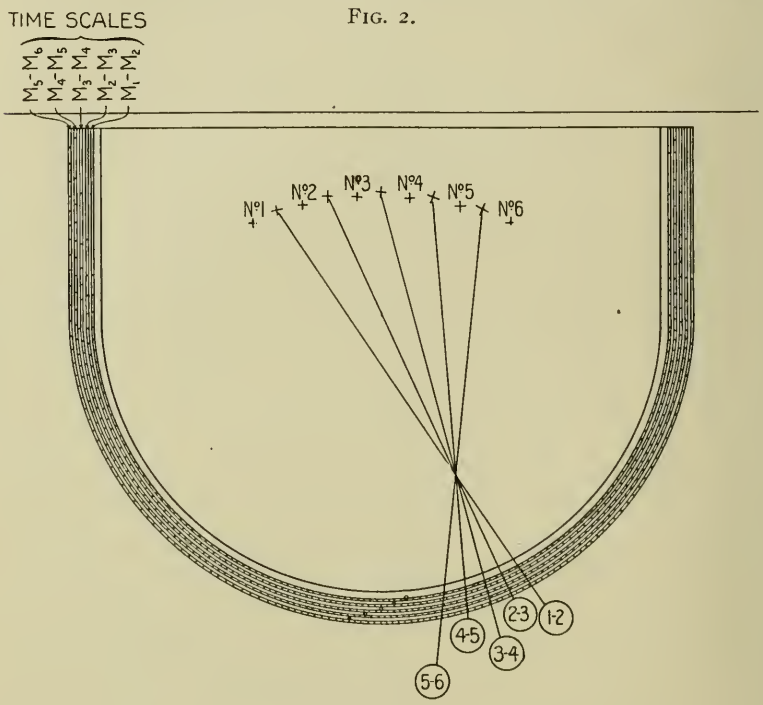
FIG. 1.



M_1 and at M_2 would be one-tenth of a second, and this time would be recorded on the timing device electrically connected with M_1 and M_2. This interval alone would not serve to locate the position of the gun, for there are a whole series of positions which the gun might occupy and still send the sound to M_1 a tenth of a second earlier than to M_2—in fact G might lie anywhere provided GM_1 were greater than GM_2 by 33·7 metres in the example chosen. Stated more mathematically, G must lie on a particular hyperbola having M_1 and M_2, as foci for an hyperbola is a curve drawn so

that the difference of the distances from any point of the curve to the two fixed points, or foci, is a constant (33.7 metres in this case). Now if G is not close to M_1 and M_2 compared to the distance between M_1 and M_2, which is the practical case on the battle front, the hyperbola on which G must lie is practically a portion of a straight line which, if prolonged, goes through a point midway between M_1 and M_2 and thus it is possible to determine the *direction* from this mid-point. A plotting board may be prepared in advance which has a string pivoted on the mid-point A, and a scale on the edge of the board marked with hundredth and tenth second intervals. In the example chosen this string would have to be set at the point marked "1/10th second left" and the gun would be determined to lie on the ground at some point represented on the plotting board as a point lying under the string. Similarly if the observed interval between the times of arrival of the report at M_2 and M_3 be laid off on a second scale for string

FIG. 2.



Plotting board.

pivoted on the mid-point B the intersection of the two strings would locate on the plotting board the position of the gun on the ground. Naturally the plotting board must be very carefully prepared from an accurate survey of the positions of the listening instruments on the ground.

The location found on the plotting board will only be exact without correction if the temperature of the air is 10 degrees centigrade and if there is no wind. If there is no wind but the temperature is greater than 10 degrees centigrade the sound will have travelled more rapidly than was assumed in the preparation of the plotting board and the intervals will thus be too small for the scale adopted in drawing the board. The amounts by which the intervals must be augmented if the temperature of the air be known are easily calculated and the strings may be set for the corrected intervals, and the intersection determines the true position of the gun as before. If a wind be blowing with a known velocity in a given direction it is only the components of this velocity which lies along the directions GM_1, GM_2, and GM_3 which will affect the times of arrival or the sound at the listening instruments; the observed intervals may therefore be easily corrected to what they would have been were there no wind and the plotting strings set accordingly.

The theory of the application of the wind and temperature corrections is an extremely simple matter, and the application itself is easy and rapid because of the graphical method of calculation employed in the construction of the string plotting board. The real difficulty lies in an uncertainty as to what the true temperature and wind are since the sound comes by a path inaccessible to observation. More than half of the path lies behind the enemy lines and the remainder lies in a region in which it is not permissible to attract the attention of the enemy by carrying out any unnecessary activities.

Three listening instruments electrically connected with a "central" or calculating station are theoretically sufficient to permit of a survey of the enemy batteries by sound; however, it is in practice advisable to employ more than three instruments for the following reasons: The electrical connections between the instruments and the time-recording mechanism at the "central" are unavoidably subject to considerable cutting by the enemy's shell-fire; it is out of the question to bury the lines to a sufficient depth

to avoid all cutting and a shallow bury renders the location and repair of breaks which do occur extremely difficult; the practice has been to lay the lines exposed on the ground and to provide a sufficient force of linesmen to ensure quick repairs. In order that the section may continue its work while such repairs are being made, six listeners instead of three are provided in the expectation that at least three will always be in working condition. If only the minimum number (three) of listening instruments are employed, no estimate of the accuracy of a location can be formed, whereas if six instruments be used the location is determined by the intersection of five strings on the plotting board; if these all intersect in a point the location is probably accurate, whereas if the intersection is poor the location is probably badly in error. A study was made of the errors corresponding to certain typical intersections and a general plan of reporting the probable accuracy of the location from the character of the intersection was adopted. The officer in command of a sound-ranging section thus reported to the artillery not only the location, target and probable calibre of an active enemy battery but also whether the location was probably accurate to fifty, one hundred or one hundred and fifty metres; these estimates were formed in a scientific manner, and all of the various sections on the front employed the same method. After a considerable number of the enemy's battery positions had been captured it was possible to check up the errors of the individual sound-ranging locations with the results of a careful survey of the positions; it was found that the estimates of accuracy had been rather too conservative, for in none of the cases examined was the accuracy less than had been claimed when the report was made, and in the majority of the cases it was considerably greater.

The recording mechanism at the "central" consisted of an accurate timing device arranged so as to photograph on a moving strip of sensitized paper a series of lines about one-fiftieth of an inch apart; these lines were the shadows cast by a set of spokes of a wheel which was kept spinning in the path of a beam of light which fell on the sensitized paper; the rate of spin of the spoked wheel was governed by a tuning fork so that the shadows were cast on the paper with the greatest attainable regularity; the rate chosen was one hundred shadows per second, so that the photographic paper had recorded across its entire width an extremely accurate time scale, the smallest interval of which was one one-

hundredth of a second; the tenth second mark and the entire second mark were made so as to be easily distinguishable from the others in order to permit rapid counting The photographic paper employed was of the standard moving picture film width, as this could be obtained quickly and at low cost both in Europe and America.

Superimposed on the time scale on the photographic paper were six lines equi-spaced across the width of the paper; these were the shadows of six moving elements of a specially constructed galvanometer, each of whose six moving elements were electrically connected to a certain one of the six listening instruments on the sound-ranging base. When the sound of an enemy gun arrived at listener No. 1 there occurred a slight twitch in the element No. 1 of the galvanometer, and this twitch was photographed on the moving photographic paper strip. The time the twitch occurred could be estimated with an accuracy of at least a hundredth of a second because the record of the time was superposed on the same piece of photographic paper. When the sound arrived at listener No. 2 the element No. 2 of the galvanometer recorded in a similar manner the exact time of arrival, and the same was true when it arrived at the listeners connected with the other four elements. Thus if the mechanism were set in motion before the sound of the gun reached the listener nearest to the gun and was allowed to run until the sound reached the listener farthest from the gun, the photographic record which was automatically developed and fixed contained all the information necessary to calculate the gun position; *i.e.*, it contained the five *intervals* between the times of arrival at the six listening instruments; if, as was generally the case, the recorder was run for twenty or thirty seconds the record usually contained the record of the burst of the enemy's shell and the position of this could also be reported to the artillery within from one to two minutes after the gun had fired.

Since a typical record not only contained data from which the position of the enemy gun could be located, but also contained data from which the location of the burst of the shell could be calculated, both the range and time of flight of the shell could be calculated. In the case of guns employing fixed ammunition charge, a knowledge of these two quantities was sufficient to determine the calibre of the gun, since the values of the muzzle

velocities of many of the German guns were well known to the Allies. Even in the case of guns not employing fixed ammunition charge the fact that the burst of the shell could be located enabled the officer in charge of the section to recover fragments of the shell on which to base an estimate of the calibre.

The possibility of an estimate of the calibre of the enemy guns was one of the unique features of sound-ranging—another important feature was the ability to locate guns which were brought up by the enemy in preparation for an attack and which were therefore not used in the period preceding the attack in order to insure an element of surprise. Such guns usually fired but one or two ranging shots, and if they were well concealed usually escaped detection by ordinary means; many such guns were located by sound-ranging when they fired their ranging shot or shots.

ACCURACY OF SOUND-RANGING IN THE A. E. F.

The limitation to the accuracy attained by the sound-ranging in the A. E. F. was partly scientific and partly set by practical working conditions. As regards the latter it is of course obvious that the necessity of mobility, the fact that any system must be operated by rather hastily trained men of average intelligence, the fact that results must generally be reported quickly to be of the greatest service, and finally the fact that an accuracy greatly in excess of that of modern artillery fire is not necessary, all preclude the use of apparatus designed solely with the object of attaining great accuracy.

The scientific limitations are in part geometrical, in part meteorological and only in part instrumental. Sound-ranging is of course a type of survey, and the accuracy to be expected is in part determined by the length of the base.

We have used six listeners equi-spaced along the arc of the circle concave toward the enemy and with the centre of the circle at or near the point about which the enemy's artillery has been grouped in the sector. This generally results in the radius of the circular arc being from 20–30 sound-seconds in length and the distance between listeners on the arc being 4, 4½ or 5 sound-seconds. (One sound-second is 337 metres.) The combination 25 sound-second radius and 4½ sound-seconds interval has been most used. Straight bases (R=infinity) have been used. The practical objection to the straight base that their use in general

results in longer films to a record is not very serious, while the theoretical objection that every location is capable of two solutions, one in front and one behind the line of listeners, applies only to the location of shell-bursts, which is a matter of no practical importance. Bases of more than 5 sound-seconds interval, while they would result in increasing accuracy, would be difficult to keep in operation on an active front because of wire cutting. On a quiet front a base of 6 seconds might be used to good effect, but it would probably have to be shortened if the front became active and this would leave a gap between neighboring sections. A better plan to secure the advantages of a long base is one we had in operation in preparation for the siege of Metz; this was to lay out adjacent sections so that they could be coupled to form one section of very long base for the more accurate location of guns of the heavier calibres.

The meteorological limitations were the most serious; these were quantitative and qualitative; that is, the exact knowledge of the direction and magnitude of the wind and the temperature were generally lacking, so that wind and temperature corrections were uncertain. Much was done to reduce this uncertainty by the British, who employed so-called wind sections near the front where empirical corrections were determined by the use of sound-ranging apparatus to secure the sound coördinates of a source of sound whose geographic coördinates were known. The factors necessary to convert the sound coördinates to the geographic were telephoned every two hours to the sound-ranging sections. This empirical method of applying wind and temperature corrections served its purpose very well and as a by-product furnished some material which should be interesting to the meteorologist. We never had to use wind sections in the A. E. F. because it was found by comparison of the data of the wind sections and those of the Army meteorological service that the actual wind velocities, directions, and temperatures, existing at a height of 50 metres gave the same over-all corrections as those obtained from the wind sections.

The limitations referred to as qualitative above were more serious. When a strong wind was blowing towards the enemy the sound was bent up so that it did not reach the listening instruments. When the wind blew from the enemy the sound reached the listeners well but the character of the records was rendered

less sharp, and so inaccuracies in the time intervals were introduced. Irregularities in temperature also produced analogous "mirage" effects which confused the records. Generally winds tended to reduce accuracy, for they necessitated screening of the listeners, which resulted in a slight decrease in sensitivity. Good screening was possible, however, and latterly the use of transformers in the circuit was coming into use. This was tried first by the Americans and was given a try-out by the British, and would probably have been adopted by both services as it did away entirely with a number of electrical complications and completely removed the irregular slow-period fluctuations due to poor wind screening. Lastly, there were instrumental limitations. Lack of sensitivity was *not* one of these—it is true that with a more sensitive recording instrument the listening instruments might have been further in the rear and greater safety to the men and less wire cutting would have resulted; however, the importance of the wind and temperature corrections which are the uncertain elements in sound-ranging would have been increased, and more than this, it was our experience that the nearer the front a section was the more efficient it was. The men kept in better touch with what was going on and had a lively interest in locating and silencing the enemy batteries whose shells fell close to the section. Besides we were able to obtain the highest grade of enlisted man for the service because it was in a sense a front-line proposition. This would not have been so had we installed our sections further to the rear. The chief danger of instrumental inaccuracy was in the timing device. The French used clockwork, which was unreliable. We, copying the British, used a timing device governed by a tuning fork which we found satisfactory with modifications suggested by a special study made to determine the effect on the rate of the fork of contact pressure, level, amplitude, mass of fork, etc. The rate of the forks was checked from time to time as an error in the timing is of course fatal to accuracy. However, instrumental timing errors are not as fatal as irregular errors in the time intervals due to meteorological causes since the instrumental errors are at least systematic and affect all the intervals proportionally while the irregular errors may amount to a large portion of the interval.

A theoretical examination of the effect of unsystematic errors leads to the result that they are about seven times as great in

range as they are in line, and that they are less the longer the sound-ranging base. Likely errors from this source in average weather and for the type of base most used are from 30–40 metres in range. In good sound-ranging weather these errors are absent. Errors likely to be introduced from lack of exact knowledge of the wind in average weather are about 30 metres, while those from uncertainty as to temperature are pratically negligible. Neither of the latter is dependent on the length of the base.

An estimate of the probable over-all error of one observation including that due to geometrical causes is expressible as follows: In the normal battle area for a 4½ second base of 25 sec. radius the probable error of a location on the right bisector to the base would be 20 metres at 4 kilometres and 80 metres at 12 km. Along a parallel to the right bisector drawn from a flank of the base it would be 50 metres at 4 km. and 100 metres at 12 km. Most of the heavy calibre guns are grouped 7 or 8 km. from the base, and the bulk of the field guns lie from 4 to 7 km. from the base.

After September 10, 1918, it was possible to survey the captured German battery positions in the St. Mihiel salient and compare the locations made by the sound-ranging with the actual surveyed positions on the ground. The locality was very favorable for a study of the accuracy of sound-ranging for two good sections had been working in the region for a period of six months —in fact from the date of the entry of the first American division into the line.

The survey was performed by the Army topographic troops, who had no direct interest in the results. The sound-ranging locations of the various active batteries were obtained from the card catalogues of activity and locations kept throughout the six months: each location bore an estimate of the probable accuracy based on the character of the intersections on the graphical plotting board at the time the location was made. The same system was in use throughout all the sections and was as follows: *P*—error not more than 50 metres, *Q*—not more than 100 metres, *R*—not more than 150 metres, *RR*—more than 150 metres. In most cases there were a considerable number of locations of each battery so that weighted mean values of the coördinates could be taken. The system of weighting was to count *P* four, *Q* three, *R* two and *RR* one.

Captain C. B. Bazzoni, Engineers, prepared a very interesting

report on the accuracy obtained by Sections 1 and 3 of which he was in command for the period March to September, 1918, an extract from which is given below. This report we had printed and distributed to all superior officers, Staff and Artillery, in the A. E. F., and to the Belgian, British, French and Italian officers in charge of sound-ranging in the armies of these nations.

The P, Q and R ratings as referring to any one location give the computing officer's critical estimate of the technical excellence of the determination. These locations result from a mathematical-physical procedure of such a nature that, if the wind and other corrections are properly applied and the atmospheric conditions are properly evaluated, the final result must positively indicate the exact source of the sound. There are in practice always certain possible errors, the limits of which must in each case be estimated by the computing officer. Although the computing officer's estimate will be more or less valuable, depending on his general grasp of the physical problem and on his knowledge of the determining factors and of their mode of variation, the data here submitted show that in our service these estimates were generally fairly true. It is evident that P locations average better than Q, Q's better than R, and R's better than RR's, and that a location, judged by a competent computing officer in the light of known weather, instrument and line conditions to be within the limits of error of one of these categories, is to a high probability actually within these limits. There are, nevertheless, possibilities for a considerably greater variation in any one individual location than might be expected. These variations are due largely to an insufficiently accurate knowledge of the weather conditions.

It is clear that since the nature of the errors involved is accidental, the average of any considerable number of locations, in themselves inaccurate, is certain to be of a much higher degree of dependability. Four or five locations made under different weather conditions constitute a considerable number in the sense here used, and the mean of these four or five can be depended upon to be close to the true battery location, even though the constituent data are all of "R" accuracy. These facts are fairly well demonstrated by the evidence examined. This statement can be otherwise expressed by saying that five or more independent "R" locations enable us to place a battery with "P" accuracy or better. It is because of these facts that Section Commanders in our service have been directed to distinguish in orders of accuracy the accuracy to be ascribed, in the judgment of the computing officer, to any one location and the accuracy of determination of a battery position from a series of observations. The order of accuracy of the mean position will, as above pointed out, be always higher than that of the constituent data and can only properly be determined through a consideration of the number of independent values involved in the mean. A battery location should be rated R on a single determination because of our necessarily uncertain knowledge of the weather conditions, although the film itself may be judged

P or Q. A "Q" can, however, safely be given to the weighted mean of four or five locations irrespective of the ratings of the individual determinations and a P can similarly be assigned to the weighted mean of eight or ten locations. The attached data show that a P battery location is safe to 25 metres. The principal factor entering into the accuracy rating of a battery position is seen to be the number of locations obtained of whatever accuracy, but it will be understood that the giving of an order of accuracy to a battery location cannot be reduced to a mere mechanical consideration of the number of independent determinations involved, even though it is mainly based on this number. The grouping of the locations should be considered and should be found normal. A normal grouping is roughly elliptical with an axial ratio of 1 to 3 or thereabouts. The major axis lies roughly on the line, battery to centre of base chord.

The batteries discussed in the group covered by this paper (The Mont Sec group) are selected from this group as typical. Persons studying this report can safely accept the conclusions to which it leads without waiting for the reports on other groups. There is no essential difference in the character of the results obtained in the different groups or in the batteries of any one group.

We can sum up by saying that a single Sound-Ranging location rated P, Q or R is to a high degree of probability within the limits of error stated for these ratings; that a mean Sound-Ranging location comprising seven to ten or more individual determinations is to a considerable degree of certainty within 25 metres of the activity centre of the battery. In consequence it is probably just to conclude that Sound-Ranging is in general practice more dependable for compiling lists of active batteries and for detecting the active part of a given battery, than any other agency. It should, however, be pointed out that the highly technical procedures involved and the breadth of general scientific knowledge required to get results of this grade consistently, demand a highly qualified, highly trained and experienced personnel and a properly handled apparatus of the general character of that in use by our sections.

The attention of readers of this report is directed to the fact that the methods used for locating active batteries by Sound-Ranging are not the ones made use of in ranging our artillery on an objective. The placing of the bursts relative to one another is accomplished by other procedures, which enable us to report the relative positions to a considerably higher degree of accuracy. It will be seen that a dispersion of locations of successive bursts, such as is shown on the attached map squares, would be of no use in correcting artillery fire. This dispersion results from the dissimilarity of weather conditions on different days. The results obtained from any one battery at any one time, roughly speaking, within three or four hours, invariably check very closely indeed with one another; but these successive determinations do not appear on our records, being looked upon as duplications.

An idea may be gained of the *amount* of artillery information supplied by the sound-ranging sections from the following extract

taken from the report of the artillery information officer of one of the American corps. This officer had at the time as sources of information three American sound-ranging sections, two American and three French flash-ranging sections, aviation and observation balloons. During a period of three weeks of rapid advance 425 separate locations of enemy batteries were made; of these the two American flash sections reported 63 per cent., the three French flash sections reported 16 per cent. and the three American sound sections reported 21 per cent. In a period of two weeks when the advance had been temporarily checked by the enemy the total number of locations was 392 and the percentages were: From three American flash sections, 38 per cent.; from two French flash sections, 8 per cent., and from three American sound sections, 54 per cent. In another and very active sector the figures were: During a period of three days' preparation for an advance, sound locations, 22; flash, 22; balloons, 0; aviation, 0. During a period of sixteen days of rapid advance: Sound, 4; flash, 46; balloons, 30; aviation, 15. During a period of four days of stabilization: Sound, 6; flash, 34; balloons, 13; aviation, 15. These figures are fairly characteristic. During preparations for an advance, both the sound and flash sections are very useful sources of information. During rapid advance the sound rangers do not get into action as often as the flash because of the greater technical difficulties. During this period the major part of the information comes from the aerial observation.

American sound-ranging sections were operating on the front from March, 1918, until the armistice, and always in sufficient numbers to cover the sectors held by American troops except for a portion of the front of the Argonne offensive when the line was moving rapidly. The work of the officers and men of the 74th Engineers engaged in this service was of a very high order, and their untiring watchfulness was often the indirect means of saving the lives of countless of their fellow-soldiers by procuring the information needed to silence the fire of the enemy guns.

THE ABSORPTION OF NUTRIENTS AND ALLIED PHENOMENA IN THE PITCHERS OF THE SARRACENIACEÆ.*

BY

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and
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THE AMERICAN PITCHER PLANTS.

THE *Sarraceniaceæ* or American pitcher plants are bog plants. In this family of plants, the entire leaf has become a pitcher with terminal lid or bilobed flap. The pitcher proper is the hollowed-out midrib of the leaf, in front of which is the wing that represents the fused halves of the blade in *Darlingtonia* and the Sarracenias; the halves are distinct but closely opposed in *Heliamphora*. The lid in *Heliamphora* and the Sarracenias and the bilobed flap in *Darlingtonia* represent a portion of the blade early separated off from the wing below as a result of the hollowing-out of the midrib between the two separated parts of the blade.[1] The developing pitcher and lid form an envelope about a hermetically sealed space—the pitcher cavity. As maturity is reached, the lid and the lips of the pitcher open, and remain in that position permanently.

The pitcher and lid or bilobed flap form a highly developed insect trap. The entire outside epidermis of the pitcher is dotted with nectar glands and forms the "alluring surface." These glands are especially abundant on the "attractive zone," which consists of the inner surface of the lid or bilobed process and the edge of the recurved, thickened rim that surrounds the orifice of the pitcher. In *Heliamphora* and the Sarracenias, the inner surface of the lid is provided with numerous hairs which are directed downward. In *Darlingtonia*, the inner surface of the bilobed flap

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Radiograph of open pitchers of *Sarracenia purpurea* (full size) containing prey. The *liquid* pitcher contents have been removed; the dense shadow represents the mass of captured insects in the lower part of the pitcher; moths, beetles and flies were identified among the captures. Radiograph by Goodspeed.

is provided with similar hairs which are directed toward the mouth of the pitcher. The interior of the pitcher may be divided into two regions. The upper or "conducting" zone has an extremely smooth lining. The lower or "detentive" zone contains long, tapered, downwardly directed hairs.

The pitcher secretes a fluid or pitcher liquor even before the lid and the lips have opened. This secretion varies in amount with the species; it may be merely a studding of minute drops of

Section of open pitcher of *Sarracenia purpurea* according to Macfarlane, showing the wing at the left, the hairy lid, the smooth conducting surface below the rim, the smooth glandular area (characteristic of this species), and the detentive zone with its downward-pointing hairs.

fluid on the lining in the lower portion of the pitcher; or it may fill the pitcher cavity to the depth of several inches. The pitcher liquor increases in volume after the lid and lips have opened, and may be further increased in certain species by rain water or by floods in their native habitat.

Great numbers of insects are attracted by the exuding nectar, probably also by the brilliant color and flower-like shape of the pitcher, and a very perceptible fruity or honey-like fragrance during the period of nectar-exudation. A creeping insect is tempted upward by the nectar on the alluring surface, and finds its way to the attractive surface. A flying insect alights on some

part of the expanded upper portion of the pitcher. The insects sip the nectar, either at the rim of the pitcher, or on the inner surface of the lid or bilobed flap, where their course is directed toward the pitcher cavity by the hairs. In either case, they step upon the smooth conducting surface, which affords no, or a very insecure, foothold, and are precipitated into the pitcher cavity. Their escape is prevented by the hairs of the detentive zone and by the smooth lining of the conducting zone. In some species, the pitcher liquor apparently exerts either a wetting or a stupefying action on the prey. The captured insects then are drowned and undergo digestion.

In this paper the species of the *Sarraceniaceæ* will be enumerated, and their geographical distribution given. Observations on the nectar, and on both the wetting and the digestive power of the pitcher liquor will be reported. A full account will then be given of the studies on absorption, by the pitchers, of compounds introduced into the pitcher cavity. Lastly, the increased secretion of liquor by the pitchers in response to stimulation by introduced substances, and their response to introduced acid and alkali will be described.

CLASSIFICATION AND GEOGRAPHICAL DISTRIBUTION.

The family, *Sarraceniaceæ,* is divided by Macfarlane [1] into three genera which include nine species:

GENUS.	SPECIES.
Heliamphora	*H. nutans*
Darlingtonia	*D. californicæ*
Sarracenia	*S. minor*
	S. Sledgei
	S. flava
	S. Drummondii
	S. rubra
	S. purpurea
	S. psittacina

The plants of this family have their native habitat in bogs.

The genus *Heliamphora,* with its single species *H. nutans,* has been reported only from Mount Roraima between British Guiana and Venezuela.

The genus *Darlingtonia,* with its single species *D. californica,* occurs only in the mountain bogs of northern California and southwest Oregon.

The genus *Sarracenia* is found in eastern North America. *Sarracenia purpurea* ranges from Labrador, Newfoundland, and Manitoba to the Gulf of Mexico. None of the other six species of this genus occurs north of Virginia or west of Texas; their southern limit is the Gulf of Mexico.

THE NECTAR.

Chemical tests show the presence of sugar in the nectar. Each of the following species was studied separately: *Darlingtonia californica, Sarracenia minor, S. Sledgei, S. flava, S. Drummondii*, and *S. purpurea*. An aqueous solution of the nectar was obtained by washing with distilled water the tops of either 25 or 50 pitchers which were exuding nectar. Each of the six solutions thus prepared reduced Benedict's copper solution, showing the presence of a reducing sugar; each yielded the characteristic crystals of phenylglucosazone with phenylhydrazine; and each gave a distinct crimson solution when heated on the water bath with resorcin and hydrochloric acid (the Seliwanoff reaction for ketose sugars). These reactions would suggest the presence of either fructose or invert sugar in the nectar. The solution of the nectar of *Darlingtonia californica* was lævorotatory; both the optical rotatory power and the copper reducing power of this solution were determined quantitatively; the results indicated the sugar to be *d*-fructose.

ACTION OF THE PITCHER LIQUOR ON LIVING INSECTS.

Mellichamp [2, 3] found that the pitcher liquor of *Sarracenia variolaris* (*S. minor*) exerted an intoxicating, anæsthetic, or narcotic action on house flies, a cockroach, a moth, and a common house spider. His results were confirmed by Watson.[4]

One of us (Jones) has found during the present research that the liquor from both closed and open pitchers of *Sarracenia flava* exerts a wetting or stupefying action on large ants. He has also found that the liquor from both closed and open pitchers of *Darlingtonia californica* does not exert such an action on large ants, bumble bees, or locusts ("grasshoppers"). The wetting or narcotic principle—when present—apparently is not a saponin, for we have obtained a negative result when the hæmolysis test for a saponin was applied to liquor from closed pitchers of *Darlingtonia californica, Sarracenia flava, S. Sledgei*, and *S. Drummondii*, and from open pitchers of *S. flava*, and *S. purpurea*.

PROTEOLYTIC ENZYMES AND BACTERIA OF THE PITCHER LIQUOR.

Zipperer [5] found that the pitcher liquor of *Sarracenia purpurea* dissolved coagulated egg white. He decided that a peptonizing enzyme was secreted by the pitcher and digested the prey.

Fenner [6] concluded that the pitchers of *Sarracenia flava* likewise secrete an enzyme which digests the captured insects.

Batalin,[7] who studied *Darlingtonia californica, Sarracenia variolaris* (*S. minor*), *S. flava,* and *S. purpurea,* speaks of the secretion, by the pitchers of these species, of a solvent for digestion of proteins.

Lambert [8] apparently considered that the pitchers of *Sarracenia purpurea* secrete a proteolytic enzyme similar to pepsin.

Hepburn, St. John, and Jones [9] detected, in the pitcher liquor of *Sarracenia flava,* a proteolytic enzyme which digested carmine fibrin. They also found, in the contents of open pitchers of *S. minor* and *S. flava,* proteolytic bacteria which digested various proteins. These studies have been extended to the other North American pitcher plants *growing in their native habitat.* The results may be summarized briefly. *Darlingtonia californica* apparently does not secrete a proteolytic enzyme, for its pitcher liquor does not digest carmine fibrin in neutral solution, or in the presence of either 0.2 per cent. hydrochloric acid or 0.5 per cent. sodium carbonate. In the genus *Sarracenia,* proteolytic enzymes (proteases) occur in the pitcher liquor of *S. minor, S. Sledgei, S. flava, S. Drummondii, S. rubra,* and *S. purpurea.* The protease in the pitcher liquor of *S. minor* and *S. flava* digests carmine fibrin, best in the presence of a dilute acid (0.2 per cent. hydrochloric); the protease in the pitcher liquor of the other species mentioned digests carmine fibrin, best in an alkaline solution containing 0.5 per cent. or less sodium carbonate. The enzyme usually is present in the liquor before the pitcher has opened. On account of the small size of the pitchers, and the small volume of their contents in *Sarracenia psittacina,* tests for a protease in the pitcher liquor and a bacteriological study of the pitcher contents have not yet been undertaken with this species.

Certain flies of the genus *Sarcophaga* pass their entire larval stage within the *Sarracenia* pitchers, living on the captured insects. These larvæ contain antiproteases;[10] this indicates that the proteases which occur in the pitcher liquor exert a digestive action on proteins present within the pitcher cavity.

In *closed* pitchers, the pitcher cavity and liquor are bacteriologically sterile. This conclusion is based on the bacteriological examination of 44 pitchers, the lids of which had not yet begun to open. Each pitcher was examined separately. These pitchers were obtained from the following species: *Darlingtonia californica, Sarracenia minor, S. Sledgei, S. flava, S. Drummondii,* and *S. purpurea.*

Bacteriological study was also made of the contents of *open* pitchers of the six species just mentioned. All the pitchers used contained captured insects. The contents of 31 pitchers were studied separately, and three examinations were made on composite samples obtained from four or five pitchers; hence 34 samples in all were examined. These pitchers always contained proteolytic bacteria which produced some or all of the following changes when sown on suitable media: Liquefaction of gelatin, coagulation and digestion of the proteins in milk, digestion of coagulated serum albumin (Loeffler's blood serum medium), digestion of coagulated proteins of whole egg (Dorset's egg medium).

ABSORPTION FROM THE PITCHER CAVITY.

Our studies show that the pitchers of the Sarracenias secrete a proteolytic enzyme, and that proteolytic bacteria are present in the pitchers of both *Darlingtonia* and the Sarracenias, in the captured insects and the liquor surrounding them. Therefore at least two means exist for the digestion of the prey. A third possible factor is the autolysis of the insect cadavers, *i.e.*, their digestion by the enzymes of their own tissues. Since digestion of the prey occurs in the pitchers, the question arises whether the pitcher absorbs the products of the digestion, and thereby makes them available for the nutrition of the plant. Several previous investigators have endeavored to determine whether absorption occurs in the pitcher cavity.

Edwards [11] considered that absorption does not occur in the pitchers of *Darlingtonia californica.* He wrote: "I do not attempt to speak authoritatively upon the subject, but I am inclined to think that no process similar to digestion goes on within the plant, but that the fluid mass derived from the decay of the imprisoned insects descends through the tube into the earth, and

is taken up by absorption, through the roots, thus acting as a kind of liquid manure."

Batalin [7] observed certain changes in the pitcher lining of *Darlingtonia californica, Sarracenia variolaris* (*S. minor*), *S. flava,* and *S. purpurea,* after insects had been captured. The pitcher cavity is lined with epidermal cells. The outer layer of the wall of these cells is the cuticular layer, and its outermost portion the cuticula. When the body of a captured insect adhered to the lining of the pitcher, the cuticula and, at times, the entire cuticular layer was cast off from the underlying cells. Batalin concluded that this change in their cell-wall occurred so that the cells might absorb nitrogenous compounds from the captured insects, and thereby satisfy the nitrogen requirement of the plant.

Schimper [12] compared the microscopic structure of pitchers of *Sarracenia purpurea* which contained captured insects or into which meat had been introduced, with that of pitchers of the same species which had been starved by plugging the mouth with tissue paper as soon as the lid had opened. The "nourished" and the "starved" pitchers differed markedly with respect to the histological structure of the protoplasm in the epidermal cells in the bottom portion of the pitcher and, to a lesser degree, in the cells of the adjacent subepidermal layer. This difference in structure was taken as evidence of absorption.

The experiments of Fenner [6] were made on *Sarracenia flava.* He noted a typical aggregation and turbidity of the contents of the cells in the bottommost zone when the pitcher contained freshly captured insects. This was most marked in the innermost layer of the pitcher-wall. A large number of dark masses occurred in the second layer of cells of the pitcher lining in this zone. These changes in the cell contents were attributed to the absorption of organic substances. When water or meat juice was introduced into a pitcher, it decreased in volume after a time, even though the mouth of the pitcher was closed with a cotton plug to prevent evaporation; therefore absorption occurred.

Goebel [13] conducted experiments on *Darlingtonia californica, Sarracenia illustrata* (a hybrid between *S. flava* and *S. purpurea*), *S. Drummondii,* and *S. purpurea.* A definite volume of water or of *one* of the following solutions was introduced into each pitcher studied: 1 per cent. formic acid, 5 per cent. peptone, dilute neutral meat infusion. In some of the experiments a minute frag-

ment of meat was introduced with the water; fibrin was introduced with the formic acid solution. Precautions were taken to prevent evaporation. A marked decrease in the volume of the pitcher contents occurred in two days, and was taken as evidence of absorption.

Lambert[8] tested the absorptive power of the pitchers of *Sarracenia purpurea* by means of certain dyes. Several drops of a solution of a crystalloid stain, such as methylene blue or fuchsin, were added to the pitcher contents; and the pitcher was cut open approximately two hours later. Staining had occurred only in the wall of the bottom region, also called the absorptive zone or "stomach." The blue or red color, according to the stain used, was found only in the internal epidermis and one or two layers of subepidermal "digestive cells" which are characteristic of this zone. A highly concentrated solution of methylene blue, introduced into living pitchers, produced the same result whether its period of action was several hours or an entire week. The epidermis and digestive cells alone were stained. The stain was absorbed, then localized; and a limit was thus placed on the total amount of absorption. Lambert concluded that the prey is digested with the production of peptones, which are absorbed by the epidermal cells and localized by the digestive cells.

Higley[14] applied the methods of quantitative chemical analysis in studying absorption from the pitcher cavity in *Sarracenia purpurea*. He made several sets of experiments. In each set he used two pitchers of the same age and size, growing on the same plant, and containing the same volume of liquor and approximately the same amount of insect remains; the pitchers selected contained but few captured insects. A quantitative determination of the "organic ammonia" was immediately made on the fluid from one of the pitchers. The other pitcher was protected so that rain could not enter, and left thus for one week; then the "organic ammonia" content of its fluid was determined, and compared with that of the first pitcher. "The fluid showed a decided decrease in each case, from the amount found in the one used in comparison. Though these analyses were perhaps quite far from sure in every detail, yet the average difference on comparison, *viz.*, sixty parts in one hundred, would indicate quite rapid absorption, for such an amount could not possibly be removed in any other way."

Darwin[15] cites Burnett[16] as stating that "*Sarraceniæ,* if kept from the access of flies, are said to be less flourishing in their growth than when each pouch is truly a sarcophagus." This observation would indicate that these plants absorb, and are nourished by, products formed in the pitchers from the captured insects.

To sum up, previous investigators have given as evidence of absorption: (1) histological changes in either the cell wall or cell contents of the pitcher lining; (2) a decrease in the volume of solutions introduced into the pitcher cavity; (3) absorption of stains, and (4) changes in the "organic ammonia" content of the pitcher liquor.

A decrease in the volume of an introduced solution indicates absorption of water, but not necessarily of the solute or dissolved substance. Apparently no one, as yet, has introduced a *known weight* of a nutrient compound into a pitcher of any of the North American pitcher plants, and studied its absorption quantitatively. However, one such experiment has been made by Clautriau,[17] who demonstrated by this means the absorption of the proteins of egg-white by a pitcher of *Nepenthes Mastersiana,* which belongs to the *Nepenthaceæ* or oriental family of pitcher plants.

ABSORPTION TESTS.

Absorption tests have been made in the field on the following species and at the following places:

Darlingtonia californica at Keddie, Plumas County, California.
Sarracenia Sledgei at Theodore, Mobile County, Alabama.
Sarracenia flava at De Funiak Springs, Walton County, Florida; and at Summerville, Berkeley County, South Carolina.
Sarracenia Drummondii at Theodore, Mobile County, Alabama.
Sarracenia purpurea in Tolland County, Connecticut.

Vigorous plants of *Sarracenia purpurea* were obtained at Whitings, Ocean County, New Jersey, and used in laboratory experiments on absorption; they were planted in sphagnum moss; and the pots were kept filled with water. The plants were kept in the laboratory for several weeks; they retained their vigor and produced new pitchers. While our experiments were conducted on freshly gathered plants, we have maintained plants in the laboratory for as long as five months.

A separate series of experiments was made concerning the absorption from the pitcher cavity of *each* of the following:

1. Water.
2. Nitrogenous compounds—chiefly organic.
3. Organic nitrogenous compounds in the presence of a "buffer."
4. Phosphates.
5. The lithium ion.

Absorption of water was studied by observation of the changes in the volume of the pitcher contents after introduction of a definite volume of water.

Absorption of nitrogenous compounds and of phosphates was measured by the retention of nitrogen or phosphates by the plant. For the study of nitrogen retention, a solution containing a known weight of a nitrogenous compound was introduced into a pitcher; the fluid remaining in the pitcher was withdrawn at the end of a given time; and the amount of nitrogen present in it was determined. The difference between this weight and the weight of nitrogen introduced was the weight of nitrogen absorbed by the pitcher and retained by the plant. Retention of phosphates was studied in exactly the same manner, using a solution of phosphates, and making determinations of phosphoric oxide.

All the nitrogen compounds used in these experiments were non-volatile, hence could not escape from the pitcher. In one series of tests of nitrogen absorption, a "buffer" solution was added to the pitcher contents to prevent the escape of any volatile nitrogenous compounds, possibly formed by reactions occurring in the pitcher cavity.

In the experiments on the absorption of the lithium ion, lithium, which does not normally occur in the tissues of the pitcher, was found in those tissues after its absorption from the pitcher contents to which it had been added.

ABSORPTION OF WATER.

Technic.—The average volume of the true pitcher liquor (*not* diluted by rain) was determined for certain species by actual measurement of the amount in large, vigorous pitchers. The upper portions of the pitcher were clipped off with scissors until the pitcher liquor was within reach of a plain pipette, the lower portion of which was of fine bore. After each portion of liquor was removed with the pipette, another section of the pitcher was cut away; and this procedure was repeated until all the liquor had been collected from the pitcher. The total liquid contents of a

definite number of pitchers were thus collected in a stoppered vial; the total volume was then determined in a narrow graduated cylinder; and the average volume was calculated. This technic was found most satisfactory for field work in the bogs which are the native habitat of these plants. The average volume, the number of lots of pitchers studied and the total number of pitchers used in obtaining the average are given in Table I.

TABLE I.

Average Volume of Liquor in the Pitchers of Certain Sarraceniaceæ.

Genus and species.	Condition of pitchers.	Number of lots measured.	Total number of pitchers used.	Average volume of pitcher liquor.
				c.c.
Darlingtonia californica	Closed	10	353	1.08
Darlingtonia californica	Open	5	161	2.80
Sarracenia Sledgei	Open	3	74	0.38
Sarracenia flava	Closed	6	566	0.66
Sarracenia flava	Open	4	160	1.50
Sarracenia Drummondii	Open	4	138	0.58

Water was introduced into pitchers of the same size and vigor as those used in the determination of the average volume of the pitcher liquor. With *open* pitchers, a definite volume of water was poured from a narrow graduated cylinder into the mouth of the pitcher; the top of the pitcher was folded over; and one or more pins were passed through the double fold. The pitchers were thus sealed, but were not injured; none of the tissues withered, not even the folded-over tops. Entrance of rain water and of insects was prevented. Identification labels of paper were inserted in the double fold, and were held in place by the pins. With *closed* pitchers, the top of the pitcher was cut off just beneath the lips or pitcher rim; a definite volume of water was poured into the pitcher cavity from a narrow graduated cylinder; and the upper portion of the pitcher was folded over and sealed as with open pitchers; the pitchers remained green and vigorous.

After the lapse of a definite period of time, the contents of these pitchers were collected, and their average volume determined. The technic was that used in the determination of the average volume of pitcher liquor as described above.

Results.—These experiments are summarized in Table II. The "shrinkage" was obtained as follows: From the sum of

the volume of water introduced plus the average volume of pitcher liquor was subtracted the average volume of the pitcher contents at the end of the experiment. For instance, open pitchers of *Sarracenia Drummondii* contain, on the average, 0.58 c.c. of pitcher liquor; each pitcher received 5.00 c.c. of water; and the average volume of the pitcher contents at the end of the experiment was 3.60 c.c. The shrinkage was $0.58 + 5.00 - 3.60 = 1.98$ c.c.

The pitcher contents of these species were so protected from rapid evaporation that the shrinkage in volume must be considered as due to absorption by the pitchers. The results indicate that but little, if any, absorption occurred in closed pitchers of

TABLE II.

Absorption of Water from the Pitcher Cavity in Certain Sarraceniaceæ.

Species.	Condition of pitchers.	Number of pitchers used in experiment.	Volume of water introduced into each pitcher.	Period of absorption.	Average volume of pitcher contents at end of experiment.	Shrinkage (allowance made for average volume of pitcher liquor).
			c.c.	*hours*	*c.c.*	*c.c.*
Darlingtonia californica	Closed	12	3.00	24	4.16	none
Darlingtonia californica	Closed	5	3.00	72	3.94	0.14
Darlingtonia californica	Closed	5	3.00	144	3.94	0.14
Darlingtonia californica	Just open	5	3.00	72	5.16	0.64
Darlingtonia californica	Just open	4	3.00	144	4.37	1.43
Sarracenia Sledgei	Open	20	5.00	7	2.95	2.43
Sarracenia flava	Closed	4	10.00	48	6.95	3.71
Sarracenia flava	Open	4	10.00	48	6.80	4.70
Sarracenia Drummondii	Open	15	5.00	7	3.60	1.98

Darlingtonia californica; in open pitchers of this species, water was absorbed, and the volume absorbed increased with the period of absorption. The volume of water absorbed was greater in open than in closed pitchers of *Sarracenia flava*, other factors being equal. Absorption of water also occurred in open pitchers of *S. Sledgei* and *S. Drummondii.*

In a laboratory experiment, seven young, vigorous, fully opened pitchers of *Sarracenia purpurea,* approximately equal in size, were freed from insect remains by thorough washing with distilled water, which was then completely removed with a pipette. Ten (10.00) c.c. of distilled water were introduced from a pipette into each *empty* pitcher, which was then closed with a tightly fitting cotton plug. Ten days later, the water was removed from

each pitcher with a serological pipette. The volumes obtained from the individual pitchers were 0.00, 6.00, 7.30, 8.10, 7.90, 6.95, and 6.10 c.c., respectively, the average volume 6.05 c.c. This experiment was repeated with six pitchers of approximately the

Mature plant of *Darlingtonia californica*, showing the twisted pitcher, and expanded hood with the orifice below, the translucent window-like spots, and the pendant bilobed flap. Photographed in Plumas County, California, where the pitchers commonly attain a height of 20 to 30 inches.

same size, each pitcher receiving 10.00 c.c. of distilled water; twenty-one days later, four pitchers contained no liquid, the other two contained 1.10 and 6.90 c.c., respectively; therefore the average volume remaining in the pitchers was 1.33 c.c. The average shrinkage in volume increased with the time, *i.e.*, was greater in twenty-one days than in ten days. The decrease in volume of the

water in the short broad pitchers of this species might be due to either absorption or evaporation, or to their combined action. The mouth of each pitcher had been tightly closed with a cotton plug to reduce evaporation to a minimum; and the plants were growing above an open surface of water. Moreover, decrease in volume of the pitcher contents due to evaporation would have been approximately equal in all the pitchers of each series. Therefore, the decrease in volume must have been due, in part at least, to absorption of water.

ABSORPTION OF NITROGENOUS COMPOUNDS.

The experiments just described demonstrated the absorption of water from the pitcher cavity by the plant. Tests were next made on the absorption of various non-volatile nitrogenous compounds when their aqueous solutions were introduced into the pitchers. Each nutrient solution contained but *one* of the following nitrogenous compounds:

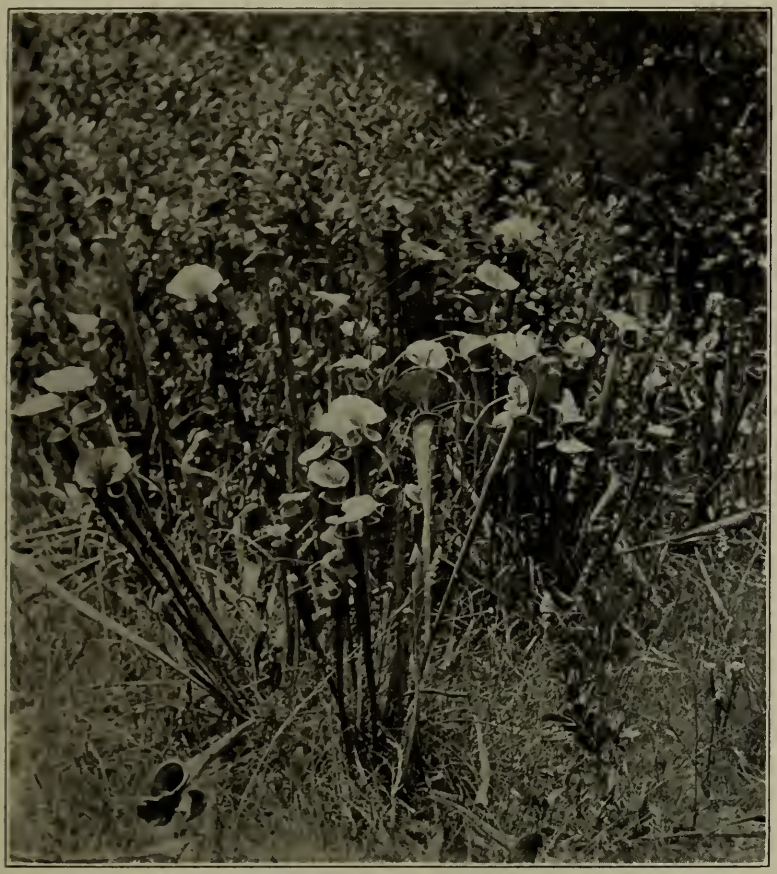
Ammonium chloride
Ammonium tartrate
Acetamide
Urea
Asparagin
Glycocoll.
Trypsinized peptone
Peptone (Witte)
Egg albumin

On digestion, a protein passes successively through the stages of protean, meta-protein, primary proteose, secondary proteose, peptone, peptides, and amino acids. Enzymes like pepsin carry digestion to the peptone stage, while enzymes like trypsin proceed farther and produce amino acids. The nutrient compounds represented several of these groups of proteolytic products. Egg albumin is a true protein; Witte peptone represents the proteoses and peptones; and glycocoll and asparagin are amino acids. Trypsinized peptone is prepared from Witte peptone by digestion with trypsin, and probably is chiefly a mixture of peptides and amino acids. Closely related to the amino acids are the acid amides such as acetamide and urea (the diamide of carbonic acid), and the ammonium salts such as ammonium chloride and ammonium tartrate. The pitchers, therefore, received nitrogenous compounds of all stages of molecular complexity from the simple

Mature plant of *Sarracenia Sledgei*, showing recently opened pitchers, the flower from which the petals have fallen, and the shrivelled pitchers of the preceding season. Photographed at Biloxi, Mississippi, where the pitchers commonly attain a height of 16 to 24 inches.

inorganic ammonium chloride and the simple organic ammonium tartrate to the highly complex egg albumin.

Each nutrient solution was prepared immediately prior to use, by dissolving the finely divided compound in distilled water, and



Group of *Sarracenia flava*, showing open pitchers, photographed in midsummer at Southern Pines, North Carolina. The pitchers of this species attain a maximum height of nearly 40 inches, though commonly between 20 and 30 inches tall.

filtering if necessary. Heat was used only in the preparation of the solution of Witte peptone; the filtered solution was cooled to atmospheric temperature prior to use. The solution of trypsinized peptone was made according to the directions of Rivas.[21] As a rule, the solutions were about tenth normal for nitrogen, *i.e.*,

contained approximately 1.4 grams nitrogen per litre. A definite volume of a nutrient solution was always introduced into a pitcher; the same volume of the same solution was used for the determination of the exact nitrogen content of the solution by the Gunning modification of the Kjeldahl method.

Technic.—The procedure with the tall slender pitchers of *Sarracenia Sledgei, S. flava,* and *S. Drummondii* was somewhat different from that with the short broad pitchers of *S. purpurea.*

In plants of the first three species, the shape and size of the pitcher made it impossible to wash out the pitcher cavity and remove the wash water before introduction of the nutrient peptone solution. Therefore, the peptone solution was introduced directly into the untreated pitcher cavity. Pitchers of three types were used: closed, open, and plugged. The technic for *closed* pitchers and *open* pitchers was that used for such pitchers in the experiments on the absorption of water; however, a peptone solution was substituted for the water. *Plugged* pitchers were pitchers which, in age and development, were open and active, but had been kept free from insect captures. Closed pitchers, which were about to open, were selected; the top of each pitcher was folded over, and one or more pins were passed through the double fold; a paper identification tag was placed in the fold. The pitcher, thus sealed, was not injured, but continued to grow, and to expand its top even above the fold; withering of the tissues never occurred. After the lapse of seven or more days, the pitcher was used in an absorption experiment; the procedure was that followed with closed pitchers.

Three days after introduction of the peptone solution, the liquid remaining in the pitcher was collected as in the experiments on absorption of water. At times, its volume was measured in a narrow graduated cylinder. The liquid was then preserved with trikresol. It and the sample of the peptone solution (likewise preserved with trikresol) were placed in stoppered vials, and brought to Philadelphia for determination of the nitrogen content.

The open pitchers of *Sarracenia purpurea* were gently flushed with distilled water from a wash bottle; the macerated mass of insects was scraped from the pitcher walls with a fine loop of platinum wire; the pitcher contents were then removed with a pipette. This process of washing was repeated several times until the pitchers were as free as possible from insect remains. A

Plant of *Sarracenia Drummondii*, showing fully open pitchers, and younger pitchers with closed lids and lips. Photographed in Mobile County, Alabama, where the mature pitchers commonly attain a height of 18 to 28 inches.

definite volume—usually, though not invariably, 10.00 c.c.—of a nutrient solution was introduced by means of a pipette into the *empty* pitcher, and the mouth of the pitcher was tightly closed with a cotton plug. From three to twelve days later, the plug was removed; it was always dry, and not soiled by the pitcher contents. The liquid in the pitcher was drawn up into a serological pipette; its volume was noted; and it was transferred to a Kjeldahl flask. The interior of the pitcher was washed with several successive portions of distilled water; these were transferred in turn by means of the pipette to the Kjeldahl flask; and the nitrogen content of the combined liquid and washings, which had a total volume of approximately 250 c.c., was determined by the Gunning method. In the field experiments on this species, a measured volume of the nutrient solution was poured into the pitcher from a narrow graduated cylinder. The sample of the nutrient solution, and the combined liquid and washings from each pitcher were placed in a separate stoppered vial, preserved with trikresol, and brought to Philadelphia for analysis.

All determinations of nitrogen were made by the Gunning modification of the Kjeldahl method. If in a vial, the liquid was transferred to a Kjeldahl flask; and the vial was washed with several successive portions of distilled water which were transferred to the same flask. If necessary, the liquid from the open pitchers of *Sarracenia flava* was filtered to remove solid insect remains, then was analyzed. A crystal of cupric sulphate the size of a small grain of rice, 10 grams of potassium sulphate, and 25 c.c. of concentrated sulphuric acid were added to the contents of the flask, which were then heated until all the water had evaporated. The determination of nitrogen was then carried out in the usual way. Tenth normal solutions of sulphuric acid and sodium hydroxide were used for titration of the ammonia, using methyl red (orthocarboxybenzeneazodimethylaniline) as an indicator.

Action of the Nutrient Solutions on the Pitchers.—Of all the nutrient solutions used, only that of ammonium chloride exerted any injurious action on the containing pitchers. On the third day after introduction of the ammonium chloride solution, the pitchers were still normal. By the sixth day, the tip of the lid had withered; and by the tenth day the withered region included the

entire lid and the rim of the pitcher. On the other hand, ammonium tartrate solution had no injurious action on the pitchers.

Toluene was introduced into the pitcher with the peptone solution in two experiments recorded at the bottom of Table III. The pitchers withered above the level of their contents, but were not injured below that level.

Tabulation of the Results.—Details of the experiments are given in Table III. Since the weight of nitrogen, and not the weight of the nutrient compound, was determined, weights have been reported as grams of nitrogen. The analysis of the nutrient solution showed the weight of nitrogen introduced; analysis of the liquid remaining in the pitcher several days later gave the weight of nitrogen recovered; the former weight minus the latter weight equalled the weight of nitrogen absorbed. The weight of nitrogen absorbed was then calculated as per cent. of the weight of nitrogen introduced.

The volume of solution introduced and that of the liquid remaining in the pitcher at the end of the experiment are given; the difference between the two is the decrease in volume, which has also been calculated as per cent. of the volume introduced. In the experiments on *Sarracenia purpurea*, this per cent. is probably an index to the absorption of the water.

Absorption by the Southern Species.—Plugged pitchers of both *Sarracenia Sledgei* and *S. Drummondii*, and both closed and open pitchers of *S. flava* always showed a marked absorption of peptone in three days; some pitchers absorbed over 40 per cent. of the introduced peptone.

In the calculation of the absorption, the nitrogen content of the pitcher liquor itself and, in open pitchers, the presence of soluble nitrogenous compounds, derived from the prey, have been neglected. They would increase both the weight of nitrogen present at the beginning of the experiment and the weight of nitrogen absorbed, by exactly the same amount, and would therefore increase the value for the per cent. of nitrogen absorbed. The influence of nitrogenous compounds derived from the prey would depend on the size and number of captured insects.

The nitrogen content of the pitcher liquor is negligible. It amounted to 0.000036 gram nitrogen per 1 c.c. of liquor in a composite sample obtained from 100 closed pitchers of *Sarracenia flava*. A composite sample from 50 open pitchers of this

species contained 0.000060 gram nitrogen per 1 c.c.; another composite sample, also from open pitchers of this species, contained 0.000050 gram nitrogen per 1 c.c., giving an average of 0.000055 gram per 1 c.c. Each sample used for an analysis had a volume of either 25 or 50 c.c. The average volume of the pitcher liquor is 0.66 c.c. in closed pitchers and 1.50 c.c. in open pitchers of *S. flava* (Table I), 0.38 c.c. in plugged pitchers of *S. Sledgei* (average of 31 pitchers), and 0.66 c.c. in plugged pitchers of *S. Drummondii* (average of 20 pitchers). In the entire series of experiments, the influence exerted by the nitrogen content of the pitcher liquor would be greatest in the experiment on four open pitchers of *S. flava*, and would change the per cent. of nitrogen absorbed from 40.49 to 40.73, an increase of about one-quarter per cent.

The liquor in the plugged pitchers may be considered to have the same nitrogen content as that in the closed pitchers of *S. flava*. On account of the smaller volume of the pitcher liquor and its lower nitrogen content, the increase in the per cent. of nitrogen absorbed, due to the nitrogen content of the liquor, would be considerably less in both closed pitchers and plugged pitchers than in open pitchers.

The changes in volume observed in the contents of the pitchers of *Sarracenia flava* may be recalculated, taking into consideration the liquor present in the pitcher at the beginning of each experiment and using the average volume of pitcher liquor as given in Table I. The recalculated percentage decrease in volume is given below; it may be considered to represent the absorption of water. For convenience, the per cent. of introduced nitrogen absorbed is repeated.

	Per cent. of introduced nitrogen absorbed.	Percentage decrease in volume.
1 Closed Pitcher	30.79	37.15
3 Closed Pitchers	42.08	39.97
1 Open Pitcher	36.84	35.65
4 Open Pitchers	40.49	40.79

The results indicate that absorption of the solute (peptone) and of the solvent (water) were not strictly parallel, and did not proceed at exactly the same rate.

Absorption by Sarracenia purpurea.—The experiments on small, poorly developed pitchers of *Sarracenia purpurea* were

made in the field in Tolland County, Connecticut. The results showed that this species absorbs ammonium tartrate, acetamide, urea, and peptone from their aqueous solutions when these solutions are introduced into the pitcher cavity.

The experiments on large vigorous pitchers of *Sarracenia purpurea* were made in the laboratory; the pitchers had recently opened. Aqueous solutions of nine different nutrient nitrogenous substances were introduced into the pitchers; and all nine substances were absorbed to a marked degree. While the "individual difference" of each pitcher entered into each test and was beyond control, the results, as a whole, uniformly had the same trend, and support the following conclusions. The absorption of nitrogenous compounds was progressive, since the per cent. of introduced nitrogen absorbed increased with the time; from 50 to 90 per cent. or more of the nutrient compound was usually absorbed in twelve days. The rate of absorption was generally greatest during the first three or four days. With the exception of the experiments on egg albumin, the per cent. of the introduced nitrogenous compound absorbed in a given time was always greater than the percentage decrease in the volume of the pitcher contents; *i.e.*, the dissolved nutrient was absorbed more rapidly than the water. This conclusion, of necessity, holds true even if part of the water was lost by evaporation.

Absorption of water from the solution occurred. The experiments on ammonium tartrate, acetamide, urea, and asparagin were begun on the same day with pitchers of approximately the same size and with the same volume of nutrient solution. They ended twelve days later. During that time, the decrease in volume of the pitcher contents varied from 22.0 to 60.5 per cent. in different experiments, while it would have been approximately equal in all experiments if due entirely to evaporation.

Egg albumin was absorbed less rapidly than the simpler nitrogenous compounds. This indicates that possibly the complex protein was digested into simpler compounds prior to absorption.

Ammonium chloride was absorbed less rapidly than ammonium tartrate. The absorption of peptone was decreased when toluene was added to the pitcher contents. The decreased absorption was possibly due to the toxic action of the ammonium chloride and the toluene on the pitchers.

TABLE III.

Absorption of Nitrogenous Compounds from the Pitchers of Species of Sarracenia

Species.	Description of pitchers.	Number of pitchers	Nitrogen compound introduced.	Period of absorption, days.	Nitrogen absorption. Weight, in grams, of nitrogen. Introduced.	Recovered.	Absorbed.	Per cent. of introduced nitrogen absorbed.	Volume changes. Volume of nutrient solution introduced.	Volume of solution recovered.	Decrease in volume.	Decrease in volume calculated as per cent. of volume introduced.
									c.c.	c.c.	c.c.	
Sarracenia Sledgei....	Plugged	1	Peptone	3	0.01422	0.00792	0.00630	44.30	.....	.....	.....	.....
	Plugged	1	Peptone	3	0.01366	0.00960	0.00406	29.72	.....	.....	.....	.....
	Plugged	1	Peptone	3	0.01450	0.01044	0.00406	28.00	.....	.....	.....	.....
	Plugged	1	Peptone	3	0.01044	0.00651	0.00393	37.64	.....	.....	.....	.....
	Plugged	1	Peptone	3	0.01044	0.00609	0.00435	41.67	.....	.....	.....	.....
Sarracenia flava.....	Closed	1	Peptone	3	0.01387	0.00960	0.00427	30.79	10.00	6.70	3.30	33.00
	Closed	3	Peptone	3	0.04644	0.02690	0.01954	42.08	40.00	25.20	14.80	37.00
	Open	1	Peptone	3	0.01387	0.00876	0.00511	36.84	10.00	7.40	2.60	26.00
	Open	4	Peptone	3	0.08133	0.04840	0.03293	40.49	70.00	45.00	25.00	35.71
Sarracenia Drummondii	Plugged	1	Peptone	3	0.01142	0.01030	0.00112	9.81	.....	.....	.....	.....
	Plugged	1	Peptone	3	0.01478	0.00932	0.00546	36.94	.....	.....	.....	.....
	Plugged	1	Peptone	3	0.01478	0.00778	0.00700	47.36	.....	.....	.....	.....
	Plugged	1	Peptone	3	0.01044	0.00658	0.00386	36.97	.....	.....	.....	.....
	Plugged	1	Peptone	3	0.01044	0.00630	0.00414	39.66	.....	.....	.....	.....
Sarracenia purpurea. (small, poorly developed pitchers)	Open	1	Ammonium tartrate	7	0.01352	0.00960	0.00392	28.99	.....	.....	.....	.....
	Open	1	Acetamide	7	0.01464	0.00736	0.00728	49.73	.....	.....	.....	.....
	Open	1	Urea	7	0.01436	0.00595	0.00841	58.57	.....	.....	.....	.....
	Open	1	Peptone	7	0.01415	0.00890	0.00525	37.10	.....	.....	.....	.....
Sarracenia purpurea (large, vigorous pitchers)	Open	1	Ammonium chloride	3	0.01499	0.01261	0.00238	15.88	.....	.....	.....	.....
	Open	1	Ammonium chloride	6	0.01499	0.01156	0.00343	22.88	.....	.....	.....	.....
	Open	1	Ammonium chloride	10	0.01499	0.01030	0.00469	31.29	.....	.....	.....	.....
	Open	1	Ammonium tartrate	4	0.01331	0.00953	0.00378	28.40	.....	.....	.....	.....
	Open	1	Ammonium tartrate	7	0.01331	0.00883	0.00448	33.66	.....	.....	.....	.....
	Open	1	Ammonium tartrate	12	0.01331	0.00658	0.00673	50.56	10.00	6.95	3.05	30.50
	Open	1	Acetamide	4	0.01464	0.00602	0.00862	58.88	.....	.....	.....	.....
	Open	1	Acetamide	7	0.01464	0.00329	0.01135	77.53	10.00	8.60	1.40	14.00
	Open	1	Acetamide	12	0.01464	0.00056	0.01408	96.17	10.00	3.95	6.05	60.50
	Open	1	Urea	4	0.01317	0.00616	0.00701	53.23	.....	.....	.....	.....
	Open	1	Urea	7	0.01317	0.00581	0.00736	55.88	10.00	9.50	0.50	5.00

Open	1	Urea	12	0.01317	0.00336	0.00981	74.49	10.00	7.80	2.20	22.00
Open	1	Asparagin	4	0.00588	0.00266	0.00322	54.76	.....	.....	.....	.....
Open	1	Asparagin	7	0.01198	0.00462	0.00736	61.44	10.00	8.00	2.00	20.00
Open	1	Asparagin	12	0.01198	0.00182	0.01016	84.81	10.00	6.30	3.70	37.00
Open	1	Glycocoll	4	0.01422	0.01121	0.00301	21.17	.....	.....	.....	.....
Open	1	Glycocoll	7	0.01422	0.00981	0.00441	31.01	10.00	8.35	1.65	16.50
Open	1	Glycocoll	12	0.01422	0.00217	0.01205	84.74	.....	.....	.....	.....
Open	1	Trypsinized peptone	3	0.01786	0.01170	0.00616	34.49	10.00	9.60	0.40	4.00
Open	1	Trypsinized peptone	7	0.01786	0.00778	0.01008	56.44	10.00	9.15	0.85	8.50
Open	1	Trypsinized peptone	12	0.01786	0.00546	0.01240	69.43	10.00	8.60	1.40	14.00
Open	1	Peptone	3	0.07061	0.06634	0.00427	6.05	25.00	23.50	1.50	6.00
Open	1	Peptone	6	0.07061	0.05842	0.01219	17.26	25.00	22.50	2.50	10.00
Open	1	Egg albumin	4	0.01765	0.01429	0.00336	19.04	10.00	8.30	1.70	17.00
Open	1	Egg albumin	7	0.01765	0.01205	0.00560	31.73	10.00	5.80	4.20	42.00
Open	1	Egg albumin	12	0.01765	0.00820	0.00945	53.54	10.00	1.90	8.10	81.00
Open	1	Peptone *	3	0.07061	0.06760	0.00301	4.26	25.00	24.50	0.50	2.00
Open	1	Peptone *	6	0.07061	0.06262	0.00799	11.32	25.00	23.00	2.00	8.00

* In these experiments, toluene was added to the contents of the pitcher.

ABSORPTION OF ORGANIC NITROGENOUS COMPOUNDS IN THE PRESENCE OF A "BUFFER."

The objection might be raised that the nitrogen, reported in Table III as absorbed, was actually converted into volatile nitrogenous compounds which escaped from the pitcher. While open pitchers of all the species used in the absorption tests have been found by us to contain bacteria which, in the Petri dish, act on simple nitrogenous compounds (glycocoll, asparagin, acetamide, urea, ammonium lactate, ammonium tartrate) with the production in the medium of a reaction alkaline to rosolic acid, and occasionally with the production of an odor of ammonia or amines, nevertheless, such an odor was never noted in the pitcher contents when they were removed for analysis at the end of an absorption test.

Reference to Table III shows that, in the presence of toluene, a bactericide, peptone was absorbed.

Additional laboratory tests on absorption were conducted, in which a "buffer" was introduced into pitchers of *Sarracenia purpurea* with the nutrient solution. Any volatile bases, formed from the nutrient nitrogenous compound by bacterial action, would be retained by the buffer, and could not escape from the pitcher.

The buffer used was an aqueous solution containing 0.4 gram monopotassium phosphate (KH_2PO_4) and 0.6 gram dipotassium phosphate (K_2HPO_4) in each 10 c.c.; a buffer solution containing these two phosphates in this ratio has been used in urinalysis to neutralize the ammonium carbonate formed by cleavage of urea by the enzyme urease.[22]

Technic.—The procedure in these experiments was exactly the same as in those on the absorption of nitrogenous compounds by *Sarracenia purpurea* described in the preceding section. However, 10.00 c.c. of the buffer solution were introduced into each pitcher at the same time as the 10.00 c.c. of the solution of the nutrient nitrogenous compound. Likewise 10.00 c.c. of the buffer solution were added to each sample of the nutrient solution used for the determination of the exact weight of nitrogen introduced.

In those experiments in which the period of absorption was seven days, the technic was modified somewhat. The pitcher was cut from the plant at its base; its exterior was cleansed with

a stream of distilled water from a wash bottle; and the cotton plug was removed from the mouth of the pitcher; it was always dry and unsoiled. The bottom part of the pitcher was cut off at the very beginning of the pitcher cavity; and the pitcher contents and subsequent washings were caught in a beaker, and passed in turn through a filter into a Kjeldahl flask. In this manner, all chances for retention of the solution of the nitrogenous compound in the narrow, bottom region of the pitcher cavity were entirely eliminated.

Results.—All four compounds—urea, acetamide, asparagin, and peptone—were absorbed in the presence of the buffer. The per cent. of introduced nitrogen absorbed usually increased with the period of absorption. Although approximately the same weight of a given compound was introduced into the pitchers in both series of experiments, the per cent. absorbed in a given time was usually less in the presence of the buffer (Table IV) than

TABLE IV.

Absorption of Organic Nitrogenous Compounds by Individual Open Pitchers of Sarracenia purpurea in the Presence of a Buffer.

Nitrogenous compound.	Period of absorption, days.	Weight, in grams, of nitrogen.			Per cent. of introduced nitrogen absorbed.
		Introduced.	Recovered.	Absorbed.	
Acetamide	4	0.01548	0.00953	0.00595	38.44
Acetamide	7	0.01548	0.00077	0.01471	95.03
Urea	4	0.01471	0.01093	0.00378	25.70
Urea	7	0.01471	0.01247	0.00224	15.23
Asparagin	4	0.01422	0.00981	0.00441	31.01
Asparagin	7	0.01422	0.00637	0.00785	55.20
Peptone	3	0.01569	0.01037	0.00532	33.91
Peptone	15	0.01569	0.00743	0.00826	52.64

in its absence (Table III). In this connection, it should be noted that the plants used in the experiments with the buffer were procured several months later than those used in the experiments on the absorption of nitrogenous compounds and the absorption of phosphates, and possibly were less active though still vigorous.

In the presence of the buffer, the pitcher contents increased in volume, while they decreased in nitrogen content. The initial volume was 20 c.c. At the end of four days, the contents of

three pitchers were withdrawn for analysis, and had the following volume:

Pitcher containing acetamide	25 c.c.
Pitcher containing urea	24 c.c.
Pitcher containing asparagin	24 c.c.

The increase in volume therefore ranged from 20 to 25 per cent.

ABSORPTION OF PHOSPHATES.

Pfeffer [18] has suggested that insectivorous plants derive both nitrogen and phosphorus from their prey. The following laboratory experiments were carried out to determine the absorption of orthophosphates from the pitcher cavity in *Sarracenia purpurea*. The plants formed part of the group secured at Whitings, New Jersey, for the laboratory experiments on absorption of nitrogenous compounds. The two series of experiments, on nitrogen compounds and phosphates, respectively, were made simultaneously but on different plants.

Technic.—The insect remains were removed from the pitchers as in the experiments on absorption of nitrogenous compounds. Then 10.00 c.c. of the phosphate solution were introduced with a pipette into each *empty* pitcher, the mouth of which was immediately closed with a tightly fitting cotton plug. The phosphate solution was exactly neutral in reaction, *i.e.*, had a hydrogen ion concentration of 10^{-7} or pH 7.0. It was prepared as directed by Levy, Rowntree, and Marriott,[23] whose procedure is based on that of Sörensen;[24, 25] 37 c.c. of a fifteenth molar solution of monopotassium dihydrogen orthophosphate and 63 c.c. of a fifteenth molar solution of disodium monohydrogen orthophosphate were mixed. The phosphate content of the resulting solution was determined by titration.

After this neutral phosphate solution had been in a pitcher for a definite period of time, varying between 7 and 20 days, the cotton plug was removed—it was always dry and not soiled by the pitcher contents; the liquid in the pitcher was drawn up into a serological pipette; its volume was recorded; and it was transferred to a beaker. The pitcher cavity was washed with several successive portions of distilled water; these were transferred in turn by means of the pipette to the beaker; and the phosphate content of the combined liquid and washings was determined by titration.

Plant of *Sarracenia purpurea* in full bloom, with open pitchers. Photographed in Ocean County, New Jersey, where vigorous pitchers attain a length of 10 or more inches.

All titrations of phosphate content were made with a standard solution of uranyl nitrate after the addition of acetic acid and sodium acetate; tincture of cochineal was used as an internal

indicator. The solution of uranyl nitrate was standardized against a definite weight of monopotassium dihydrogen phosphate as suggested by Giles.[26] Results were calculated as grams of phosphoric oxide, P_2O_5.

The difference between the weight of phosphoric oxide introduced into the pitcher and the weight of phosphoric oxide recovered in the fluid and washings from the pitcher represented the weight of that compound absorbed from the cavity by the pitcher.

Results of these experiments are given in Table V, and lead to the following conclusions. Absorption of phosphates occurred in all the pitchers. The individual pitchers do not show any

TABLE V.

Absorption of Phosphates from the Pitchers of Sarracenia purpurea.

Number of pitchers.	Period of absorption, days.	Weight, in grams, of phosphoric anhydride.			Per cent. of introduced phosphoric anhydride absorbed.		Volume changes.			
		Introduced.	Recovered.	Absorbed.			Volume of phosphate solution introduced.	Volume of solution recovered.	Decrease in volume.	Decrease in volume calculated as per cent. of volume introduced.
							c.c.	c.c.	c.c.	
1	7	0.04681	0.03515	0.01166	24.91	Average 21.68	10.00	3.50	6.50	65.00
1	7	0.04681	0.03818	0.00863	18.44					
1	12	0.04681	0.03636	0.01045	22.32	Average 22.98	10.00	6.00	4.00	40.00
1	12	0.04681	0.03575	0.01106	23.63		10.00	5.90	4.10	41.00
1	20	0.04681	0.03303	0.01378	29.44	Average 26.86	10.00	5.45	4.55	45.50
1	20	0.04681	0.03545	0.01136	24.27		10.00	5.85	4.15	41.50

definite relation between the period of absorption and the per cent. of the introduced phosphoric oxide absorbed. When the two experiments of each period are averaged, and the averages are compared, the absorption appears to have been progressive throughout the entire 20 days, but to have been most rapid during the first 7 days. In a given time, the pitcher contents usually showed a greater percentage decrease in volume than in phosphoric oxide content; this indicates that water was absorbed more rapidly than phosphates from the solution in the pitcher cavity.

ABSORPTION OF THE LITHIUM ION.

These experiments were also made on plants of *Sarracenia purpurea* in the laboratory. A double normal solution of neutral lithium citrate ($Li_3C_6H_5O_7$) was prepared from lithium car-

bonate and citric acid. The solution was filtered; and 20 c.c. of the filtrate were introduced into each of four open pitchers, which were then closed with tightly fitting cotton plugs. One pitcher was examined at the end of seven days, the other three pitchers at the end of fourteen days. Each pitcher was cut from the plant at its base; and its exterior was well washed with a stream of distilled water from a wash bottle. The cotton plug was removed; the bottom portion of the pitcher was cut off just above the beginning of the pitcher cavity; the contents were permitted to run out; all insect remains were removed with a platinum needle; and the entire interior of the pitcher was repeatedly flushed, and its lid and exterior washed with distilled water until the wash water no longer imparted the lithium color to the non-luminous Bunsen flame.

The pitcher was next dried at 100° C., then ashed, in a platinum crucible. The ash was treated with 0.5 c.c. of concentrated hydrochloric acid and 2.0 c.c. of distilled water; and the resulting solution was filtered through a small, moistened, ashless filter-paper.

Lithium was identified in this solution of the ash by the crimson color imparted to the non-luminous Bunsen flame, and by spectroscopic examination of this colored flame by means of a Hofmann direct vision spectroscope with a scale previously calibrated for the lithium and sodium lines. The ash from all four pitchers yielded the same result.

As a control, examination was made of a composite sample of dried tissue obtained from fifty-nine open pitchers of *Sarracenia purpurea* which had been thoroughly cleansed from insect remains. These pitchers were obtained at the same time and place (Whitings) as the plants used in the tests on absorption of lithium. The dried tissue was ground so that it passed completely through a sieve with 20 meshes to the linear inch. A five-gram sample of the ground tissue was ashed in platinum. A loop of platinum wire was dipped into concentrated hydrochloric acid, then into the ash, and finally was placed in the non-luminous Bunsen flame. Neither the flame reaction (color) nor the spectral line of lithium appeared.

These results show that lithium is not a normal constituent of the tissues of *Sarracenia purpurea*, and that the pitchers of

this plant absorb the lithium ion from its neutral solution when such a solution is introduced into the pitcher cavity.

The spectroscopic examinations were made, in collaboration with Dr. Charles B. Bazzoni, in the Randal Morgan Laboratory of Physics of this University.

RESPONSE OF THE PITCHERS TO STIMULATION.

In 1875 Mrs. R. M. L. Austin, a California botanist, discovered that the introduction of meat into the pitcher cavity causes the pouring out of an additional supply of pitcher liquor in *Darlingtonia californica.* The following quotation is from a letter written by Mrs. Austin to Mary E. Pulsifer Ames, and was published by the latter:[19] "In July, 1875, I fed a great many of the leaves, some with fresh raw mutton and others with that which was boiled. The liquid, in the course of a week, would fill the tubes and flow out of the orifice." According to Asa Gray,[20] Mrs. Austin, studying *Darlingtonia californica,* found that "the watery liquid in the pitcher, which must be wholly a secretion, is much increased in quantity after the capture of insects."

In certain of our experiments in the field, a definite volume of a solution was introduced into pitchers which were then closed in the manner described in the sections on absorption. After the lapse of a definite period of time, from one to ten days, the average volume of the pitcher contents was determined in the usual way. From this average volume was subtracted the sum of the volume of solution introduced plus the average volume of the pitcher liquor in pitchers of the same species and same type (closed, open, or plugged); the remainder was the average increase in volume of the liquid pitcher contents, due to outpouring of additional liquor as the result of stimulation of the pitchers by the introduced solution. This average increase in volume was then calculated as per cent. of the average volume of the pitcher liquor of such pitchers.

Fresh skim milk was diluted with an equal volume of water, sterilized by heat, cooled to atmospheric temperature, and used in stimulation tests. The *average increase amounted to as much as* 1200 per cent. in 6 days in closed pitchers of *Darlingtonia californica,* 1000 per cent. in 4 days in closed pitchers of *Sarracenia flava,* and 900 per cent. and 500 per cent., respectively, in

5 days in plugged pitchers of *S. Sledgei* and *S. Drummondii.* With a given species and pitchers of a given type, the increase became more marked, the longer the time elapsed between introduction of the diluted milk and withdrawal of the pitcher contents, and the greater the volume of milk introduced.

Beef broth produced an *increase* of over 300 per cent. in pitchers of all three types in *Darlingtonia californica* in 5 days. It also produced increases of over 1700 per cent. and 600 per cent., respectively, in closed and open pitchers of *Sarracenia flava* in 4 days; the increase in one closed pitcher was over 2400 per cent.

Increases in the volume of the pitcher secretion were produced by certain reagents: dilute solution of potassium ferrocyanide, dilute solution of potassium ferricyanide, 2 per cent. solution of ferrous sulphate. The ferrous solution was introduced into pitchers of *Sarracenia Sledgei, S. flava,* and *S. Drummondii,* the other solutions into pitchers of *S. flava* only. A 2 per cent. solution of ferric ammonium sulphate, to which sodium acetate had been added, killed the pitchers of all three species within a few days after its introduction.

When introduced into the pitchers, raw egg-white produced no change in the volume of the pitcher liquor. This was also true of certain solids: coagulated egg-white, fibrin, casein, and cheese.

In the experiments on *Darlingtonia californica,* cubes of lean beef were introduced into the pitchers by means of forceps, and fell to the level of the pitcher liquor. Each edge of a cube was one-eighth inch long. When raw beef was used, an increase in volume of the pitcher liquor occurred in pitchers of all three types —closed, open, and plugged—but was always less than 200 per cent. in 7 days. When cooked beef was used, little, if any, increase took place in the volume of the liquor in either open or plugged pitchers.

This phenomenon of secretion of an abnormal volume of pitcher liquor is not in conflict with that of absorption. The decrease in volume of the pitcher contents, as a rule, occurred less rapidly than the absorption of nitrogenous compounds, and more rapidly than the absorption of phosphates from their respective solutions. Moreover, in the absorption experiments in which a buffer was added to the solutions of the nitrogenous compounds,

those compounds were absorbed while the pitcher contents increased in volume. An increase in volume of the pitcher contents also occurred in the experiments on the absorption of the lithium ion. In the plant economy, this increased secretion probably represents a result of natural selection, in which there has gradually developed a rise in the level of the pitcher liquor that insures the covering of captured insects which otherwise would lie in a dry and undigested state above the normal level of that fluid.

RESPONSE OF THE PITCHERS TO INTRODUCED ACID AND ALKALI.

Dilute aqueous solutions of acids (hydrochloric and acetic) and of sodium hydroxide were also introduced into the pitchers of certain species, and the pitcher contents examined 5 days later.

The pitcher liquor in open pitchers of *Darlingtonia californica, Sarracenia Sledgei,* and *S. Drummondii* and in plugged pitchers of *D. californica* is neutral to litmus, that in closed pitchers of *S. flava* acid, and that in open pitchers of *S. flava* faintly acid to neutral to litmus. The solutions introduced into the pitchers were tested, and possessed either a distinctly acid reaction (hydrochloric acid, acetic acid) or a distinctly alkaline reaction (sodium hydroxide) to litmus. Each pitcher received a definite volume (from 3 to 30c.c., usually 5c.c.) of a solution of *one* of the reagents.

The acetic acid was used as a 0.05 per cent. solution with the species of *Sarracenia* just mentioned, and as a 0.10 per cent. solution with *Darlingtonia californica.* Within 5 days, the reaction of the pitcher contents to litmus had become neutral in the plugged pitchers of *Darlingtonia californica,* in the open pitchers of that species, *Sarracenia Sledgei,* and *S. Drummondii,* and in the closed pitchers of *S. flava,* and was acid in the open pitchers of the last-named species. The volume of the pitcher contents showed a marked decrease in all the *Sarracenia* pitchers, and a slight increase in those of *D. californica.*

The hydrochloric acid was usually used as a 0.05 per cent. solution. Within 5 days, the pitcher contents had become neutral to litmus in open pitchers of *Darlingtonia californica,* and *Sarracenia Drummondii,* and in the majority of those of *S. Sledgei;* they were faintly acid to litmus in both open and closed pitchers of *S. flava.* The *Sarracenia* pitchers showed a decrease in the volume of their contents. A 0.2 per cent. solution of hydrochloric

acid was also introduced into both open and plugged pitchers of *D. californica;* some pitchers were injured, becoming partly shriveled and brown; their contents were faintly acid to litmus; other pitchers were unharmed, their contents were neutral to litmus at the end of the 5 days.

Sodium hydroxide was used as a 0.02 per cent. solution in both open and plugged pitchers of *Darlingtonia californica,* and as a 0.05 per cent. solution in open pitchers of *Sarracenia Sledgei* and *S. Drummondii* and in both open and closed pitchers of *S. flava.* Within 5 days, the contents of the pitchers had become neutral to litmus in all the experiments. The pitcher contents decreased in volume in the *Sarracenia* pitchers and increased slightly in volume in those of *Darlingtonia californica.*

It is of interest to note that, in the experiments with acids, an acid reaction was retained only in the pitchers of *Sarracenia flava;* the pitcher liquor of this species normally tends to have an acid reaction, and its protease acts best in an acid medium.

After the introduction of either dilute acid or dilute alkali into the pitchers, the normal reaction of the pitcher contents was restored, as a rule, in a few days. This return of the pitcher contents to their normal reaction recalls the behavior of the human stomach under somewhat similar conditions, as studied by Spencer, Meyer, Rehfuss, and Hawk.[27]

SUMMARY.

I. A résumé has been given of our observations on:

1. The occurrence of reducing sugar in the nectar.

2. The wetting action of the pitcher liquor on insects.

3. The occurrence of a proteolytic enzyme in the pitcher liquor of the Sarracenias and its absence from that of *Darlingtonia californica.*

4. The freedom from bacteria of the pitcher cavity and liquor in closed pitchers.

5. The occurrence of proteolytic bacteria in the contents of open pitchers, in which captured insects were present.

6. The secretion of additional pitcher liquor in response to stimulation by certain foods such as milk and meat broth, and by certain other substances.

7. The response by the pitchers to introduction of acid or alkali in dilute solution.

II. A detailed account has been given of our studies on absorption by the pitchers of substances introduced into their cavities. These studies led to the following general conclusions:

1. Water, which was introduced into the pitchers of *Darlingtonia californica* and the Sarracenias, underwent absorption.

2. When an aqueous solution of a nitrogenous compound was introduced into pitchers of the Sarracenias, both the nitrogenous compound and the water were absorbed, but at a different rate; absorption of the nitrogenous compound was usually more rapid than that of the water.

3. When a phosphate buffer was added to the aqueous solution of the nitrogenous compound, the latter was absorbed while the pitcher contents increased in volume.

4. When a neutral phosphate solution was introduced into pitchers of *Sarracenia purpurea,* both the phosphate and the water were absorbed, but at a different rate; absorption of the phosphate was less rapid than that of the water.

5. The per cent. of the introduced nitrogenous compound or phosphate absorbed usually increased with the period of absorption.

6. When a solution of neutral lithium citrate was introduced into pitchers of *Sarracenia purpurea,* the lithium ion was absorbed.

7. Absorption by the pitchers of substances introduced into their cavities in solution has been demonstrated (*a*) by the decrease in the nitrogen or phosphate content of the solution, and (*b*) by appearance in the pitcher tissues of lithium, an element not normally present.

8. These results indicate that the proteolytic products, formed in the pitcher cavity by digestion of the prey, are absorbed by the pitchers and are utilized for the nutrition of the plant. They also indicate that phosphates, and probably other mineral foods, derived from the prey, are absorbed and utilized in like manner.

The authors are deeply indebted to Dr. John M. Macfarlane, director of the botanic laboratory and garden of this University, who has placed all the facilities of his department at their disposal, and has offered many suggestions of great value to them. They also acknowledge with pleasure the hearty coöperation of the staff of the Randal Morgan Laboratory of Physics of this

University. The radiographs of pitchers containing captured insects are the work of Dr. Arthur W. Goodspeed; Dr. Horace C. Richards collaborated in the fluoroscopic examination of such pitchers, and Dr. Charles B. Bazzoni in the spectroscopic examination of the ash.

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(Citations numbered 1 to 20 inclusive refer to insectivorous plants. The remainder of the papers cited deal with methods of research.)

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Method of Cleaning Coil Springs. DONALD A. HAMPSON. (*Machinery*, vol. xxvi, No. 4, p. 343, December, 1919.)—A certain manufacturer who produces coil springs from copper-finished steel wire had considerable trouble in keeping them bright and free from oil. These springs are two inches long and have an extension at each end that projects at right angles to the axis of the spring. In the production of these springs, the use of lubricant is imperative in the operation of the forming machine, which results in the presence of oil on the finished product. Unless this oil is removed, the bright copper finish of the wire becomes dull, and thus the selling qualities are lessened. This objection is now overcome by the method to be described.

The springs are packed in a wooden box having a removable cover. A one-inch shaft passes through the box and is secured to its sides by flanged collars. The shaft is supported by a bearing on each side of the box, and carries a driving pulley on one end by means of which the box is revolved at the rate of forty revolutions per minute. After the box has been filled with springs, a quantity of sawdust is dumped in and the cover fastened on. By revolving the box for about twenty minutes, the sawdust is circulated through the springs, during which process the oil is completely absorbed and the springs are given a uniform polish. The springs tend to become tangled if the box is revolved longer than the time stated, or if the box is only partly filled.

R.

Test of Alpine Tanks.—The tank in peace-time is to be applied to transporting passengers and goods to hotels on mountains where carriage roads are lacking. A test of this method of mountain climbing was held September, 1919, in the Department of France in which Mt. Blanc is situated. The course was 4.7 km. long with an ascent of .7 km. over mule tracks, peaty ground, and meadow land, through fords and along deep ravines. The Renault caterpillar tractor made the ascent in 83 minutes, the descent in 66 minutes, and completed three trips in a day.

G. F. S.

THE RELATIVE MERITS OF MONOCULAR AND BINOCULAR FIELD-GLASSES.*

THE RESULTS OF AN INVESTIGATION UNDERTAKEN BY THE SUB-COMMITTEE OF THE NATIONAL RESEARCH COUNCIL ON "MONOCULAR *versus* BINOCULAR FIELD-GLASSES."

BY

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THE investigation of the relative merits of monocular and binocular field-glasses was undertaken by members of the staff of Nela Research Laboratory upon request from the National Research Council. In the first instance the Laboratory was asked for a critique of the literature on the subject, but since this failed to establish definitely any decisive advantages for the binocular, it was deemed wise to institute an extensive investigation of the problem.

To this end a comprehensive program of procedure was formulated, as outlined in the Introduction, but owing to the urgent demand for the completion of the investigation it was necessary to omit certain parts of the program and to depend upon the findings of the practical field test which, according to the plan of work, should constitute the final stage of the investigation. Unfortunately, therefore, the research is not complete, but the results of the field test are sufficiently indicative to justify certain tentative conclusions.

Except for the Introduction, which covers briefly the survey of the literature of the subject, as given in the critique referred to above, and which also includes an outline of the program of work as formulated at the beginning of the investigation, the

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* Communicated by Edward P. Hyde.

[1] The Committee is indebted to Messrs. Cobb and Weniger for practically all of the experimental work.

text of the present paper is quite closely a verbatim copy of the report transmitted to the National Research Council.

INTRODUCTION.

The general problem of the relative merits of monocular and binocular field-glasses is many-sided; comparisons may be made on the basis of mechanical and optical design and construction, on questions of pure physiologic optics, and on the use and manipulation of the glasses under service conditions.

A comparison of the two types of glasses as to their mechanical properties yields the following: The limits of toleration for departure from parallelism of the optic axes of the two telescopes of a binocular are very small. Consequently, the instrument may be rather easily thrown out of alignment by falls and blows, and as a result cause an undue amount of eye fatigue. The binocular requires three adjustments (separate focus for each eye, and adjustment of interpupillary distance) to fit it to the eyes of a particular observer, and in the type adopted by the army (without means of focussing both telescopes simultaneously) the focus cannot be conveniently changed while the instrument is in use; the same hand that holds the monocular can also focus it at any time. The binocular of the type adopted by the army (prism adjustment and not objective adjustment) cannot be cleaned thoroughly in the field on account of resultant lack of parallelism of the axes upon reassembling; there is no such trouble with the monocular. The binocular is bulkier and heavier and requires a leather carrying case with a shoulder strap, which is always in the way; the monocular can be carried in a shirt pocket and is instantly ready for use. The speed of production of the binocular is slower, and its cost is about three times that of the monocular.

The questions of physiologic optics that enter into this comparison are of two kinds:

(1) Those concerning the stereoscopic effect, and

(2) Those concerning any possible increase in visual sensitivity apart from the stereoscopic effect.

With regard to the stereoscopic effect, it is to be remarked that the factor which governs the absolute perception of depth is the parallax, *i.e.*, the difference between the two angles sub-

tended at the two eyes respectively by the images of two points of different remoteness in the field. The parallax, so measured, and hence the sensitivity to depth, is obviously increased directly as the magnification, and is also increased directly as the distance between the objectives of the binocular.

Magnification has the effect of proportionately decreasing the apparent depth of objects relatively to their transverse dimensions; while increasing the distance between the objectives apparently decreases both size and distance without distortion.[2] Neither of these appearances is to be taken as an index to depth-sensitivity, which depends solely upon the considerations mentioned in the preceding paragraph.

The distance between the objectives of prism binoculars as ordinarily constructed is approximately 1.75 times the normal interpupillary distance. Taking 65 mm. as the normal interpupillary distance, and 30 seconds as an average value of the parallax angle that can be detected by an observer, a simple computation shows that with a binocular magnifying six diameters, a point at a distance of 4670 metres from the observer can just be distinguished as being nearer than an infinitely distant background. For a glass magnifying eight diameters, this distance is 6250 metres. In other words, for viewing objects at distances greater than the above, the binocular offers no advantage over the monocular from the standpoint of stereoscopic effect.

It seems obvious that an appearance of relief would reveal to binocular vision an object monocularly indistinguishable from its more remote and variegated background. The influence of this factor on visual sensitivity to detail seems to have escaped experimental attack, although it is quite apparent in the use of the simple stereoscope.

With reference to visual sensitivity apart from steroscopic effect, it seems to be established that binocular observation for the ordinary individual gives a greater sensitivity to brightness and to differences of brightness than monocular observation yields; and this holds true for both dark-adapted and light-adapted eyes. It has been asserted also that visual acuity, or sensitivity to detail, is higher for binocular vision than for monocular, but we have been unable to locate any reports of quantitative experiments. It

[2] Pulfrich, *Zeit. f. Instk.*, 25, 1905, p. 233.

also appears in the work of Dawson [3] that the time required for making a difficult photometric judgment is considerably shorter, and the percentage of accuracy greater, for binocular observation than for monocular.

Data on questions attending the use of the glasses in practice, such as the time required for "picking up" a distant object, the time required for distinguishing the detail on it, etc., do not seem to be on record. This survey of the field shows clearly that the experimental work of the committee lies for the most part along two lines:

(1) Investigations of some of the problems in physiologic optics under out-of-door conditions, using field-glasses, the results of which may in some cases merely substantiate conclusions reached by pure laboratory study without glasses, and

(2) A statistical study of the results obtained with the two types of glasses when used by men who were training for work requiring the use of glasses in warfare.

An additional question that is certainly worthy of study, and is applicable to both monoculars and binoculars, is that of distinguishing colored objects from their surroundings by the use of suitable colored screens, when such objects are indistinguishable in ordinary light. The use of colored screens should aid vision also by the exclusion of scattered light and by the reduction of the effect of chromatic aberration in the eye.

Plans were therefore made to ascertain the relative merits of the two types of glasses by an experimental study of the following problems:

(1) Non-stereoscopic acuity tests under daylight illumination,

(2) Non-stereoscopic acuity tests under twilight illumination,

(3) Effect of parallax on the discrimination of detail,

(4) Discrimination of objects possessing a brightness difference and the effect of parallax on this discrimination, and

(5) Effect of colored screens in the eye-piece on the discrimination of detail and brightness differences.

Unfortunately, work on the last three of these was stopped by an urgent request to conduct the statistical study with military officers as observers. The latter was carried on at Camp Meade, Maryland, under the immediate supervision of the Board to Test Snipers' Equipment, Colonel Wm. P. Jackson, Chairman.

[3] *Brit. Jour. Psych.*, 6, 1913, p. 78.

PART I.

NON-STEREOSCOPIC ACUITY TESTS UNDER DAYLIGHT ILLUMINATION.

THE first question to which an answer was sought in this comparative study of monocular and binocular vision was whether the two eyes, acting in harmony, have appreciably greater sensitiveness than either one alone; to make it concrete, whether both together can distinguish small details with greater speed and accuracy than either one alone when those details are presented on a flat field at such a distance that vision must be aided by the use of a field-glass.

CONDITIONS, APPARATUS AND PROCEDURE.

The work was conducted under the open sky upon the grounds of the Mayfield Country Club, near Cleveland. The weather, during the course of the experiments which enter into the results, was variable—sometimes clear, sometimes slightly hazy, sometimes cloudy and usually breezy. At times the wind was such as to make it difficult to maintain the position of the glass before the eyes with a sufficient degree of steadiness.

The land lay so that between the observer and the object there were three depressions. The four eminences on this range—the position of the observer being one—were of such height that the line of vision passed over them at about the height of an ordinary individual's eyes. From the last of these the land sloped gently downward toward the test object, so as to cut off the observer's view of all objects at that point less than about 130 cm. from the ground.

To conduct the work it was necessary to communicate rapidly between the two ends of the range, something over half a mile. This was made possible by a system of visible signals and the use, at either end of the line, of a terrestrial telescope having a magnifying power of sixty diameters. The atmospheric impediments, although absolutely less effective, were naturally most obvious through these telescopes, more so than with the unaided eyes or with a field-glass of comparatively low magnification. A marked heat-shimmer was thus often observed over the range, almost always when the sun was shining. On such days as the sky was

partially clouded there would be periods of sunlight and shade over the range, and often a nearly maximal heat-shimmer would be observed to appear almost immediately following the appearance of the sunlight, to disappear again as quickly as a cloud shaded the range.

The appearance of the test object can be best described by saying that it was a white square on a black ground with a central strip, in area one-third of the square, removed, thus leaving two white bars (see Fig. 1). Taking the width of one bar as unity, the space between them is 1, and their length is 3. By a specially devised mechanical arrangement this figure could be changed proportionately in all its dimensions, the width of the bars and the intervening space decreasing by indefinite gradations from 12 cm. to 0 with a simultaneous and proportional decrease in the length of the bars from 36 cm. to 0. The case enclosing the mechanism, a shallow box, 90 cm. square, could be rotated about a central axis normal to its face so as to present the bars inclined at any angle.

The sizes of the test object are designated by numbers, and the consecutive sizes differ in the ratio of $1 : \sqrt[8]{\frac{1}{2}}$. The largest is designated *0*, where the width of the white bars is 12 cm. Therefore, if n be the numeral designating the size, the width of each bar will be $12(\frac{1}{2})^{n/8}$ cm. The sizes for the various designations are given in Table I, along with the angles subtended (without magnification) at the observer's station.

TABLE I.

Stimulus No.	Width cm.	Angle min.	Stimulus No.	Width cm.	Angle min.	Stimulus No.	Width cm.	Angle min.
0	12.00	0.431	8	6.00	0.216	16	3.00	0.108
1	11.00	.395	9	5.50	.198	17	2.75	.099
2	10.09	.363	10	5.05	.182	18	2.52	.091
3	9.25	.333	11	4.63	.166	19	2.31	.083
4	8.49	.305	12	4.24	.152	20	2.12	.076
5	7.78	.280	13	3.89	.140	21	1.95	.070
6	7.14	.257	14	3.57	.125	22	1.78	.064
7	6.54	.235	15	3.27	.118	23	1.64	.059
8	6.00	.216	16	3.00	.108	24	1.50	.054

In the experiments the test object was shown to the observer in only two positions, with the bars either horizontal or vertical. He was required, at a word, to look at the object with the glass and announce the position in which he saw the bars to be.

The stimuli comprising a series of experiments, as finally settled upon, were ten to twelve consecutive sizes of the object, presented each once in the vertical and once in the horizontal position. These were presented in shuffled order determined in advance and written on duplicate protocol sheets. One of these was in the hands of the recorder, whose place was at the side of the observer, and the other was used by the operator of the test object at the other end of the range.

The order of procedure was as follows. The operator set the

FIG 1.

Operator's station.

test object to the size and position of the first stimulus of the series, according to his sheet, and signalled "ready." The recorder, receiving the signal, gave the word "go" to the observer and started a stop-watch as the latter raised the glass to his eyes. The observer announced to the recorder the instant he distinguished the position of the test object by the word "up" for the vertical, "down" for the horizontal position. In the third case, as soon as he was satisfied that he could not distinguish the position of the object he spoke the word "cross." By means of a semaphore (Fig. 2), he signalled the same answer to the

operator at the other end of the range. The recorder wrote the answer and the time of observation on his sheet, and the operator wrote the answer signalled and at once set the object for the next stimulus and gave the "ready" signal. The observer, upon receiving the signal by way of the recorder, acknowledged it by throwing the semaphore arm into a meaningless position and again awaited the word "go." Several check signals were ex-

FIG 2.

Observer's station.

changed in the course of the series to make sure of agreement on the order. The recorder's sheet was the one preserved, after being checked with the other.

For investigating one eye alone, a cap with a ground-glass bottom was slipped over the opposite objective of the field-glass. With each observer three series were always run in immediate succession—right eye alone, left alone, and both eyes—the order of these three being systematically varied in all possible permutations. The three observers assumed the duties of recorder and operator in rotation with as few departures from regularity as were consistent with practical convenience. The work was done from August 30 to September 25, 1917, and between the hours

9.00 A.M. and 5.30 P.M. The observer was always standing with no additional support for any part of his body, nor for the glass. The test object was 956 metres distant from him in a direction south 40° east. Before and between series he focussed the glass, and also *ad libitum* during observation.

The instrument used was a Leitz prism binocular having a magnifying power of six diameters and 7/8-inch objectives. This instrument was chosen from among those at hand (including a five- and a ten-power navy binocular), largely because it was provided with a simultaneous focussing adjustment, which the others lacked, as well as with a separate adjustment for one eye. Its magnification also seemed best suited for experimentation at the available distance.

Upwards of 4000 experiments were made. The earlier portion of these was considered to be vitiated by the lack of special experience, so that about 3600 have been taken into account in computing the results following.

RESULTS.

The results, including all of the data from the latter group of experiments, are given in Tables II, III, and IV. It is to be noticed that under those conditions in which both right (R) and indeterminate (X) answers were given, the average time for the indeterminate answer is almost always longer than the average time required for the right answer. This simply means that the observer did not prematurely give up the attempt to appreciate the direction of the stripes on the test object. On the average, he devoted more time to the observation than was necessary to see the test object correctly in the favorable cases.

At worst, the object appeared as a small white blur, of variable size. In some cases it would have a fluctuating appearance, the direction appearing at one instant vertical, at another horizontal. This might continue until the observer gave up the attempt to name the direction. Or possibly, after a period of indistinctness or fluctuation, the bars would flash into consciousness in a vivid way that was unmistakable. Often, on the other hand, after prolonged observation, the answer was rendered with misgivings and proved to be correct. Usually, if the object was of such size as to be at or near the limit of visibility, the observer would feel himself impelled to continue his efforts. When the

object was much below the critical region he apparently recognized the fact and gave up his efforts to see it earlier than in the corresponding cases with a larger stimulus. This fact appears from the tables in examining the times under the heading *X*.

In a very few cases the observer returned an answer which was positively wrong. *A priori* this would suggest that he had guessed at the position of the object and missed it. On this supposition it would have to be further considered that he had also guessed right, probably with equal frequency and that hence his number of truly right answers—that is, the number in which he could be supposed to have actually seen the object—would be the recorded number less the number of wrong answers. However, the scarcity of wrong answers, the (often) long time taken in rendering them, and the fact that in the case of observer G. H. (who returned the largest number) they occurred under conditions within which no doubtful judgments whatever were given, made it appear that the wrong answers were not due to careless observation, nor to guessing, but rather to the supervention of some unusual condition in the observer. It was, therefore, decided to leave them entirely out of consideration. As a matter of fact, the final results are only very slightly altered by so doing.

On examining the recorded times required for observation, it was noticed that of the experiments under any one condition a few showed inordinately long times, as though these also represented conditions much out of the usual run. To these groups (representing practically all the observations) Chauvenet's criterion was applied, and the experiments having improbable time values were also eliminated. The remaining data are given in Tables II-A, III-A, and IV-A.

The values in the last-mentioned tables were used in making the plots (Figs. 3, 4, and 5). Average times representing less than five results were not plotted. The especial points to be noticed in these are:

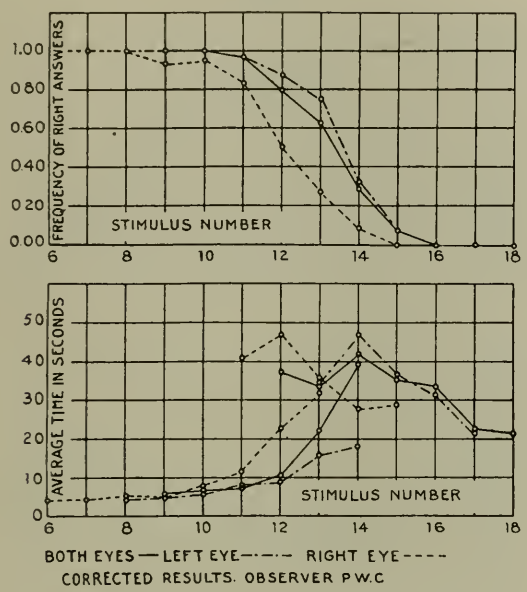
(1) With relatively large stimuli the time of observation is small, two to eleven seconds, increasing rather rapidly with decrease in stimulus size once the region is reached where the indeterminate judgments appear.

(2) With stimuli of such size that both right and indeterminate judgments appear, the time required is larger for the latter than for the former.

(3) The time of observation required for indeterminate judgments is longer in the stimulus-region of mixed judgments than it is with smaller stimuli where indeterminate judgments are the rule.

In the separate use of each eye alone all three of the observers showed distinctly better results with one eye than with the other. The fact that the better results were obtained with the right eye

FIG 3.



of one observer (W. W.) and with the left of the other two (P. W. C.) and (G. H.) would indicate that the difference was not due to imperfect matching or adjustment of the optical parts of the binocular.

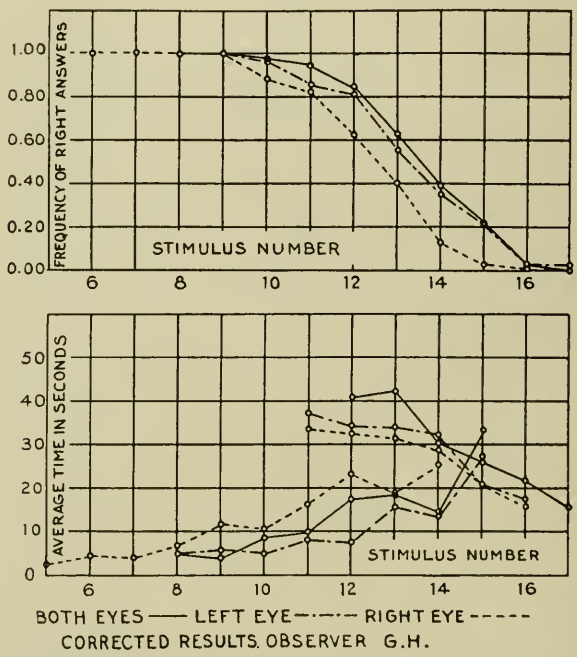
The final comparison to be made is between the results obtained with the better eye alone, and those obtained binocularly.

In the case of observer P. W. C., the results obtained with the left eye alone were distinctly better than those obtained with the two eyes together. It appears further that the difference between the two eyes is greater in the case of this observer than for either of the others, the binocular results falling in an intermediate position (Fig. 3). Measured as difference in the size of the test object the left eye is about 4 per cent. better than both, the right

11 per cent. poorer. These differences are computed from the segment of the abscissa line corresponding to 50 per cent. frequency cut off by the respective pairs of curves in the plot.

With this observer the times run a course parallel with the degree of uncertainty of judgment. At stimulus No. 12, to illustrate, the frequencies of right answers are 0.500 with the right eye, 0.794 with both, and 0.875 with the left. The corresponding

FIG 4.



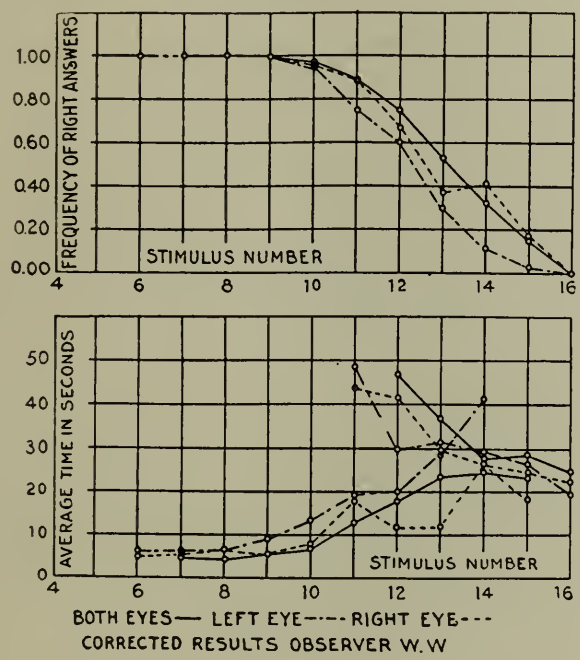
times are 22.6, 10.3, and 7.9 seconds, greater as vision is more uncertain and *vice versa*. It would seem that this observer had distributed his time fairly consistently with the difficulty of observation.

Turning to the plot of the results of observer G. H. (Fig. 4), we see that in his case the frequencies of right answers for binocular vision are greater than for either eye alone, the left and right eyes falling below to the extent of about 2 per cent. and 6 per cent. respectively. Referring to the time plot we see that the right eye falls off in frequency in spite of the greater time consumed in observation. On the contrary, with the left eye, as

compared with binocular vision the frequency is only slightly less, and the time of observation is also less, leaving open the possibility that the apparently better results with both eyes may be due to more careful observation rather than to binocular synergy.

The results of observer W. W. (Fig. 5) do not readily admit of estimations on which to base quantitative comparisons. His left eye shows about 7 per cent. poorer vision than both together.

FIG 5.



The frequencies for the right eye plot irregularly, and at stimuli Nos. 12 and 13 only does there appear to be a material advantage in favor of binocular vision. A glance at the time plot shows that here again the greater certainty of vision is accompanied by greater time of observation. In other words, the case is the same at these two points as it is in general for observer G. H.

The uncorrected data examined in the manner of the foregoing furnish no contradictory evidence. In general the differences just pointed out, both as to frequency and time, are less in amount, and the relations between them, therefore, less clear cut.

CONCLUSIONS.

The point investigated in this part of the work is whether in the use of a binocular field-glass the two eyes reinforce each other to any material extent. The conditions are full daylight illumination, and the criterion is vision of detail of minimal size and maximal contrast in a test object located entirely in one plane normal to the line of sight.

In the cases of two of the observers the eyes used singly show differences of about 4 per cent. and 7 per cent., respectively, in acuity. *No decisive advantage was found in the use of the two eyes together over the use of the better eye alone.*

In the third observer there was a difference in acuity of about 15 per cent. between the two eyes, and in his case *the use of both eyes gave results about 4 per cent. poorer than the use of the better eye alone.*

Such differences as were found to exist between the two eyes of the several observers would be difficult or impossible to detect by means of usual ophthalmologic practice. The observers could not be considered to have abnormal vision in the accepted sense of the term.

It is here to be remembered that in the two cases (monocular and binocular vision) the task of raising the glass to the eyes and maintaining it in proper position has, by the mode of procedure, been made identical. If this work had, on the contrary, been conducted with monocular and binocular glasses as supplied to the market, it seems obvious that the results would have been influenced to a great extent by the relative degrees of stability possible with the respective mountings.

EXPLANATION OF TABLES II–IV AND II-A–IV-A.

Tables II, III and IV are computed from all of the results in the experiments considered. *R* indicates "right answer," *W* "wrong" and *X* undetermined.

Under "Time" is given in each case the average time required for observation, followed by its mean deviation. Under "Number" will be found the number of experiments entering into the respective average time. The "frequency" applies to the stimulus-value, and is here the fraction of the whole number of experiments upon that stimulus in which right answers were given.

Tables II-A, III-A and IV-A were similarly prepared after eliminating those experiments in which wrong answers were given and those in which the time of observation was of improbable length (see page 194).

TABLE II.

Summary of Results.

A Tabulation of the Number of Right (R), Wrong (W), and Indeterminate (X) Answers for Each Size of Stimulus Presented; the Average Length of Time Required for Each of the Above Sets of Answers, Together with Their Mean Deviations; and the Statistical Frequency of the Occurrence of Right Answers.

Observer P. W. C.

Stimulus Number	Time in Seconds			Number			Frequency
	R	W	X	R	W	X	$R/(R+W+X)$
			Both eyes.				
9	7.1 ± 3.7	.....	.....	41	0	0	1.000
10	8.2 ± 4.2	.....	.....	41	0	0	1.000
11	12.3 ± 7.6	.....	82.0 ± 0	40	0	1	0.976
12	15.3 ± 8.8	31.0 ± 0	37.1 ± 14.4	33	1	7	0.805
13	27.0 ± 13.8	30.0 ± 19.0	38.9 ± 12.8	24	2	15	0.586
14	39.0 ± 16.2	46.0 ± 0	45.8 ± 18.1	11	1	29	0.268
15	31.3 ± 16.2	.....	37.5 ± 12.2	3	0	38	0.073
16	.....	.....	35.5 ± 10.3	0	0	38	0.000
17	.....	.....	25.1 ± 8.6	0	0	38	0.000
18	.....	.....	22.2 ± 7.5	0	0	38	0.000
			Left eye.				
8	5.1 ± 1.6	.....	.....	38	0	0	1.000
9	5.6 ± 1.8	.....	.....	41	0	0	1.000
10	7.4 ± 3.4	.....	.....	41	0	0	1.000
11	14.2 ± 10.4	.....	33.0 ± 0	40	0	1	0.976
12	14.8 ± 10.5	.....	33.8 ± 5.3	37	0	4	0.902
13	24.5 ± 15.2	35.0 ± 0	42.0 ± 12.4	30	1	10	0.732
14	28.3 ± 15.4	.....	46.7 ± 16.0	16	0	25	0.390
15	20.0 ± 2.7	.....	38.6 ± 13.0	3	0	38	0.073
16	.....	.....	33.2 ± 12.6	0	0	38	0.000
17	.....	.....	24.2 ± 7.3	0	0	38	0.000
			Right eye.				
6	4.8 ± 1.4	.....	.....	38	0	0	1.000
7	5.2 ± 2.1	.....	.....	38	0	0	1.000
8	6.3 ± 2.4	.....	.....	38	0	0	1.000
9	10.0 ± 7.5	.....	43.0 ± 17.0	39	0	2	0.951
10	12.0 ± 7.9	.....	29.0 ± 2.0	39	0	2	0.951
11	15.6 ± 8.8	.....	47.1 ± 12.4	34	0	7	0.829
12	22.6 ± 11.6	.....	50.0 ± 13.6	20	0	21	0.488
13	31.9 ± 13.1	77.0 ± 0	39.9 ± 10.5	10	1	30	0.244
14	31.3 ± 3.8	.....	31.0 ± 9.2	3	0	38	0.007
15	.....	.....	28.8 ± 8.4	0	0	41	0.000

TABLE II–A.

Corrected Results.

A Summary Similar to Table II, but with Wrong Answers Omitted and Huge Time-values Eliminated by the Application of Chauvenet's Criterion.

Observer P. W. C.

Stimulus Number	Time in seconds		Number		Frequency
	R	*X*	*R*	*X*	$R/(R+X)$
		Both eyes.			
9	5.6 ± 1.8	.....	37	0	1.000
10	6.1 ± 2.0	.....	36	0	1.000
11	7.0 ± 1.5	82.0 ± 0	29	1	0.967
12	10.3 ± 3.3	37.1 ± 14.4	27	7	0.794
13	22.0 ± 9.5	33.6 ± 8.1	21	13	0.617
14	39.0 ± 16.2	41.8 ± 14.3	11	27	0.289
15	31.3 ± 16.2	35.3 ± 10.5	3	36	0.077
16	.....	33.3 ± 8.8	0	36	0.000
17	.....	22.7 ± 6.5	0	34	0.000
18	.....	21.4 ± 6.8	0	37	0.000
		Left eye.			
8	4.4 ± 0.9	.....	33	0	1.000
9	4.8 ± 1.0	.....	37	0	1.000
10	5.7 ± 1.4	.....	36	0	1.000
11	7.5 ± 2.5	33.0 ± 0	31	1	0.969
12	7.9 ± 2.7	33.8 ± 5.3	28	4	0.875
13	15.6 ± 6.2	34.6 ± 6.2	24	8	0.750
14	18.2 ± 5.0	46.7 ± 16.0	12	25	0.324
15	20.0 ± 2.7	36.7 ± 11.0	3	37	0.075
16	.....	31.5 ± 11.0	0	37	0.000
17	.....	21.8 ± 5.6	0	34	0.000
		Right eye.			
6	4.0 ± 0.5	.....	31	0	1.000
7	4.1 ± 0.8	.....	33	0	1.000
8	5.0 ± 0.7	.....	33	0	1.000
9	4.8 ± 0.8	43.0 ± 17.0	27	2	0.931
10	7.8 ± 2.9	29.0 ± 2.0	33	2	0.943
11	11.4 ± 4.7	40.8 ± 8.2	29	6	0.829
12	22.6 ± 11.6	46.9 ± 11.2	20	20	0.500
13	31.9 ± 13.1	35.8 ± 6.7	10	27	0.270
14	31.3 ± 3.8	27.6 ± 3.8	3	34	0.081
15	.....	28.8 ± 8.4	0	41	0.000

TABLE III.

Summary of Results.

A Tabulation of the Number of Right (R), Wrong (W), and Indeterminate (X) Answers for Each Size of Stimulus Presented; the Average Length of Time Required for Each of the Above Sets of Answers, Together with Their Mean Deviations; and the Statistical Frequency of the Occurrence of Right Answers.

Observer G. H.

Stimulus Number	Time in seconds			Number			Frequency
	R	W	X	R	W	X	$R/(R+W+X)$
			Both eyes.				
8	4.7 ± 1.8	.....	.....	38	0	0	1.000
9	7.0 ± 4.5	23.0 ± 0	.....	40	1	0	0.976
10	10.2 ± 7.3	.....	53.0 ± 0	40	0	1	0.976
11	15.2 ± 11.6	23.5 ± 2.5	34.0 ± 6.0	37	2	2	0.902
12	19.1 ± 13.2	41.5 ± 22.5	40.7 ± 14.0	33	2	6	0.805
13	18.4 ± 10.0	32.0 ± 0	42.1 ± 11.0	25	1	15	0.610
14	18.9 ± 10.1	31.0 ± 13.0	33.0 ± 12.0	16	2	23	0.390
15	33.1 ± 16.6	.....	25.8 ± 8.4	9	0	32	0.219
16	12.0 ± 0	.....	23.8 ± 9.6	1	0	37	0.026
17	.....	.....	19.2 ± 8.3	0	0	36	0.000
			Left eye.				
8	7.1 ± 4.9	11.0 ± 0	.....	37	1	0	0.974
9	6.7 ± 4.0	22.0 ± 0	.....	40	1	0	0.976
10	10.4 ± 7.3	.....	42.0 ± 0	40	0	1	0.976
11	12.3 ± 8.3	.....	37.2 ± 7.0	36	0	5	0.878
12	13.1 ± 8.9	9.0 ± 0	34.3 ± 8.7	34	1	6	0.830
13	20.0 ± 14.1	38.0 ± 0	34.0 ± 10.0	23	1	17	0.561
14	22.7 ± 16.4	17.5 ± 3.5	34.6 ± 15.5	15	2	24	0.366
15	27.3 ± 11.0	42.5 ± 9.5	28.3 ± 13.0	7	2	32	0.171
16	9.0 ± 0	120.0 ± 0	20.5 ± 9.1	1	1	37	0.026
17	14.0 ± 0	.....	17.7 ± 7.3	1	0	36	0.027
			Right eye.				
5	4.9 ± 3.1	.....	.....	38	0	0	1.000
6	4.4 ± 1.7	.....	.....	38	0	0	1.000
7	5.6 ± 3.0	8.0 ± 3.0	.....	39	2	0	0.951
8	8.1 ± 5.3	4.0 ± 0	.....	40	1	0	0.976
9	11.4 ± 7.1	13.0 ± 2.0	.....	39	2	0	0.951
10	14.5 ± 10.7	.....	46.5 ± 9.8	37	0	4	0.902
11	18.0 ± 12.5	.....	39.8 ± 14.8	33	0	8	0.805
12	23.0 ± 14.9	11.0 ± 0	32.2 ± 18.7	25	1	15	0.610
13	18.8 ± 8.9	35.0 ± 0	31.1 ± 10.4	16	1	24	0.390
14	25.2 ± 8.6	24.5 ± 19.5	28.7 ± 12.9	5	2	34	0.122
15	17.0 ± 0	17.0 ± 0	23.4 ± 8.7	1	1	36	0.026
16	.....	.....	18.7 ± 7.3	0	0	38	0.000

TABLE III–A.

Corrected Results.

A Summary Similar to Table III but with Wrong Answers Omitted, and Huge Time-values Eliminated by the Application of Chauvenet's Criterion.

Observer G. H.

Stimulus Number	Time in seconds		Number		Frequency
	R	*X*	*R*	*X*	*R/R(+X)*
		Both eyes.			
8	4.7 ± 1.8	.....	38	0	1.000
9	4.0 ± 0.9	.....	30	0	1.000
10	8.3 ± 5.2	53.0 ± 0	38	1	0.974
11	9.6 ± 5.0	34.0 ± 6.0	33	2	0.943
12	17.1 ± 11.2	40.7 ± 14.0	32	6	0.842
13	18.4 ± 10.0	42.1 ± 11.0	25	15	0.625
14	14.6 ± 6.1	30.5 ± 9.4	14	22	0.389
15	33.1 ± 16.6	25.8 ± 8.4	9	32	0.220
16	12.0 ± 0	21.8 ± 7.7	1	35	0.028
17	.....	15.5 ± 4.8	0	31	0.000
		Left eye.			
8	4.9 ± 2.2	.....	33	0	1.000
9	5.3 ± 2.3	.....	37	0	1.000
10	4.9 ± 1.2	42.0 ± 0	26	1	0.963
11	7.9 ± 3.8	37.2 ± 7.0	29	5	0.853
12	7.4 ± 2.4	34.3 ± 8.7	26	6	0.812
13	15.4 ± 9.4	34.0 ± 10.0	21	17	0.553
14	13.6 ± 8.6	32.2 ± 12.8	12	23	0.343
15	27.3 ± 11.0	20.7 ± 5.8	7	26	0.212
16	9.0 ± 0	17.3 ± 6.0	1	34	0.029
17	14.0 ± 0	13.8 ± 3.9	1	30	0.032
		Right eye			
5	2.9 ± 0.6	.....	29	0	1.000
6	4.4 ± 1.7	.....	38	0	1.000
7	3.9 ± 1.0	.....	33	0	1.000
8	6.7 ± 3.8	.....	38	0	1.000
9	11.4 ± 7.1	.....	39	0	1.000
10	10.3 ± 6.4	46.5 ± 9.8	33	4	0.892
11	16.0 ± 10.3	33.4 ± 9.6	32	7	0.821
12	23.0 ± 14.9	32.2 ± 18.7	25	15	0.625
13	18.8 ± 8.9	31.1 ± 10.4	16	24	0.400
14	25.2 ± 8.6	28.7 ± 12.9	5	34	0.128
15	17.0 ± 0	20.4 ± 6.1	1	33	0.029
16	.....	15.6 ± 4.2	0	33	0.000

TABLE IV.

Summary of Results.

A Tabulation of the Number of Right (R), Wrong (W), and Indeterminate (X) Answers for Each Size of Stimulus Presented; the Average Length of Time Required for Each of the Above Sets of Answers, Together with their Mean Deviations; and the Statistical Frequency of the Occurrence of Right Answers.

Observer W. W.

Stimulus Number	Time in seconds			Number			Frequency
	R	W	X	R	W	X	$R/(R+W+X)$
			Both eyes.				
7	5.1 ± 1.8	.....	.....	36	0	0	1.000
8	6.5 ± 4.0	.....	.....	42	0	0	1.000
9	7.3 ± 3.6	.....	.....	42	0	0	1.000
10	10.9 ± 7.6	.....	45.0 ± 0	41	0	1	0.976
11	17.1 ± 12.0	.....	63.8 ± 38.8	38	0	4	0.904
12	22.5 ± 15.8	.....	46.8 ± 17.3	33	0	10	0.767
13	34.9 ± 24.0	90.0 ± 0	41.7 ± 11.7	22	1	19	0.524
14	32.5 ± 17.8	63.0 ± 3.0	33.9 ± 14.0	13	2	27	0.309
15	34.0 ± 20.3	.....	30.0 ± 11.1	7	0	35	0.167
16	.....	.....	27.8 ± 10.6	0	0	36	0.000
			Left eye.				
6	6.0 ± 2.4	.....	.....	36	0	0	1.000
7	8.0 ± 4.1	.....	.....	36	0	0	1.000
8	8.1 ± 3.9	.....	.....	42	0	0	1.000
9	11.1 ± 6.6	.....	.....	42	0	0	1.000
10	16.4 ± 9.8	.....	38.5 ± 11.5	40	0	2	0.952
11	20.5 ± 13.0	.....	53.5 ± 16.3	31	0	11	0.738
12	20.9 ± 9.6	.....	31.2 ± 6.9	25	0	17	0.595
13	28.2 ± 14.3	.....	33.2 ± 8.8	12	0	30	0.286
14	41.4 ± 9.7	.....	29.3 ± 9.3	5	0	37	0.119
15	45.0 ± 0	.....	26.1 ± 8.3	1	0	41	0.024
16	.....	.....	20.6 ± 5.4	0	0	30	0.000
			Right eye.				
6	6.1 ± 3.1	.....	.....	36	0	0	1.000
7	5.9 ± 2.2	.....	.....	36	0	0	1.000
8	12.7 ± 10.6	.....	.....	42	0	0	1.000
9	7.5 ± 3.2	.....	.....	42	0	0	1.000
10	14.9 ± 11.0	26.0 ± 21.0	55.0 ± 0	39	2	1	0.929
11	17.5 ± 11.7	.....	43.6 ± 8.9	38	0	5	0.884
12	21.4 ± 17.8	.....	41.1 ± 9.9	30	0	12	0.714
13	19.9 ± 11.3	.....	32.6 ± 9.0	19	0	23	0.452
14	26.1 ± 16.0	.....	35.7 ± 14.8	15	0	27	0.357
15	18.3 ± 9.5	.....	26.0 ± 8.1	7	0	35	0.167
16	.....	.....	25.6 ± 8.4	0	0	32	0.000

TABLE IV–A.

Corrected Results.

A Summary Similar to Table IV but with Wrong Answers Omitted, and Huge Time-values Eliminated by the Application of Chauvenet's Criterion.

Observer W. W.

Stimulus Number	Time in seconds		Number		Frequency
	R	*X*	*R*	*X*	$R/(R+X)$
		Both eyes.			
7	4.5 ± 1.3	.....	34	0	1.000
8	4.2 ± 1.3	.....	35	0	1.000
9	5.3 ± 1.6	.....	35	0	1.000
10	6.8 ± 2.6	45.0 ± 0	35	1	0.972
11	12.6 ± 7.0	63.8 ± 38.8	34	4	0.895
12	17.6 ± 11.4	46.8 ± 17.3	30	10	0.750
13	23.2 ± 12.0	36.6 ± 6.7	19	17	0.528
14	24.2 ± 10.6	27.6 ± 8.0	11	23	0.324
15	23.2 ± 7.8	28.3 ± 7.1	6	33	0.154
16	.....	24.8 ± 8.0	0	33	0.000
		Left eye.			
6	6.0 ± 2.4	.....	36	0	1.000
7	6.2 ± 2.8	.....	33	0	1.000
8	6.5 ± 2.2	.....	33	0	1.000
9	8.7 ± 4.0	.....	40	0	1.000
10	13.0 ± 6.4	38.5 ± 11.5	36	2	0.947
11	18.9 ± 11.5	48.3 ± 18.0	30	10	0.750
12	19.7 ± 8.6	29.5 ± 7.3	24	16	0.600
13	28.2 ± 14.3	31.3 ± 8.3	12	28	0.300
14	41.4 ± 9.7	29.3 ± 9.3	5	37	0.119
15	45.0 ± 0	26.1 ± 8.3	1	41	0.024
16	.....	19.4 ± 4.3	0	28	0.000
		Right eye			
6	4.6 ± 1.3	.....	34	0	1.000
7	5.1 ± 1.5	.....	33	0	1.000
8	6.2 ± 1.7	.....	34	0	1.000
9	5.8 ± 1.5	.....	36	0	1.000
10	7.4 ± 2.2	55.0 ± 0	29	1	0.967
11	17.5 ± 11.7	43.6 ± 14.3	38	5	0.884
12	11.6 ± 7.5	41.1 ± 9.9	24	12	0.667
13	11.6 ± 3.3	29.6 ± 6.7	13	21	0.372
14	26.1 ± 16.0	26.4 ± 5.1	15	21	0.417
15	18.3 ± 9.5	24.3 ± 6.6	7	33	0.175
16	.....	22.2 ± 5.3	0	29	0.000

PART II.

NON-STEREOSCOPIC ACUITY TESTS UNDER TWILIGHT ILLUMINATION.

CERTAIN investigations by Piper [4] in the functions of the eyes have shown a mutual reinforcement of the two eyes when these were adapted to light of low intensity by a period of darkness, while the same eyes coming immediately from the light showed no such reinforcement. The test object in his work was a field of considerable extent, and the measure of sensitivity was the lowest brightness at which the field could be seen. At first, after coming from the light into the dark room, it was found that the lowest perceptible brightness was the same, whether one or two eyes were used. In the course of an hour in the dark the sensitivity of vision, measured by this criterion, increased enormously; and at the end of that period it was found that the lowest perceptible brightness for one eye was nearly or quite double that required for binocular vision.

This and other facts that have appeared from research in physiological optics have given rise to a theory of two-fold function of the retina. The anatomical representatives of the two functions are respectively the rods and cones, and the theory, briefly stated, follows:

(1) The cones of the retina are exclusively, or at least predominantly, functional at ordinary daylight intensities; and also below this to the point where colors cease to be differentiated as such.

(2) At this point the rods have exclusively assumed the function of vision, the cones dropping out by reason of their lower sensitiveness.

This theory is borne out by abundant evidence. A series of experiments upon the eye, extending through both these ranges of intensity, almost invariably shows that vision accords with different laws in the two regions. These two modes of vision are so distinct that they have received the respective designations, "daylight vision" and "twilight vision."

The present work was undertaken as supplementary to the work treated in Part I of this report, and the aim was to investi-

[4] Klin. Monatsbl. f. Augenheilk, 3, 1907, p. 357.

gate the same point under twilight illumination. It was conducted with the same apparatus and by the same methods as far as was consistent with this essential condition.

APPARATUS AND PROCEDURE.

Natural twilight is invariably a rapidly changing quantity, and, therefore, for purposes of experiment it is necessary to simulate it by artificial means which may be held in a constant state. This work was then necessarily performed under cover. It early appeared that the relatively short distances available in laboratory rooms of ordinary size were inadmissible for the purpose. The degree of convergence required of a pair of eyes looking through a prism binocular is greater by two factors than that required, at the same actual distance, of the unaided eyes. These factors are: (1) the ratio of the axial separation of the two objectives to that of the subject's eyes, and (2) the magnification of the glass. In the present case the product of these two factors (1.75×6) is 10.5. At a distance of 7 metres, with the glass, a (computed) degree of convergence is required corresponding to a distance of 67 cm., which in turn tends to induce accommodation for that distance. That such accommodation takes place to some extent is shown by the simple experiment of focussing the two limbs of the binocular separately and monocularly on an object at, say, 7 metres; then in attempting to use it with both eyes it will be found to be no longer in focus for the same object. Satisfactory refocussing was not practicable under the light conditions planned. Increasing the illumination and involving an additional loss of time waiting for the subject to readapt to the experimental condition was inexpedient. This detail of the problem was finally solved by finding a range of adequate length.

The work was actually carried out in one of the underground tunnels at Nela Park, constructed and used as a conduit for pipes and electric wires. A stretch of tunnel was available which easily made possible a range of 81.65 metres, measured from the eyes of the observer to the test object. The convergence demanded in the use of the binocular at this distance is equal to that required in ordinary vision at a distance of ($81.65/10.5 =$) 7.8 metres. The grade of accommodation corresponding to this distance and degree of convergence is well below the limit accepted in the practice of ophthalmology as negligible.

The clear space in the tunnel, left as a runway, has a width of 1.4 metres, and its height is sufficient to permit a man of average height to walk easily without stooping. The observations were made from a seated posture, one of the observers being somewhat too tall to stand comfortably in the tunnel. Signals were exchanged by means of buzzers between the experimenter and the observer.

The test object was illuminated by projecting upon it the much enlarged image of a highly illuminated disc of milk glass set in the side of a Thorington ophthalmological chimney. Within the chimney was a 40-watt tungsten filament vacuum lamp kept at a constant current. Over the lens which projected the image of the disc was placed a piece of blue glass known as "north skylight glass" which with the lamp used gave light of an approximate daylight color.

The illumination upon the test object from this device measured, at the conclusion of the experiments, with a Macbeth Illuminometer was found to be 0.011 metre candle (0.0012 foot candle). At this low illumination and with the white stripes of the test object the only visible objects, it was found difficult, in some cases, to get the glass oriented upon the object at all promptly. Further, actual outdoor twilight vision almost never occurs in this way. The object is almost always, in this case, seen upon a large field, of very low brightness and vague in detail, but sufficiently distinct to act as a guide in orientation with or without the glass.

To obviate this trouble a foreground was constructed. It was a frame of light boards having a central rectangular opening 1.26 metres high by 0.82 wide. The width of the sides, top, and bottom of the frame (about 30 cm.) made it large enough to fill the cross-section of the tunnel, 1.9 by 1.4 metres. This frame was painted white and hung at a distance of 15.5 metres from the observer. By a separate light it was illuminated to a point that made observation convenient, but never to appear brighter than the test object. This was left to the discretion of the individual observer, and for him it was kept always the same. While actually observing through the glass, the field appeared about as

shown in Fig. 6. For one of the observers, P. W. C., who wore glasses, the field was restricted so that the top and bottom were not simultaneously visible.

Before the begininng of each experimental session the subject was allowed to sit in his place under the experimental conditions in order that his eyes might become dark adapted. The time required for this was variable, from five to twenty minutes or so, the observer judging for himself what was adequate, guided largely by the disappearance of the subjective shadows which he

FIG 6.

Appearance of field.

perceived during this time, drifting about his visual field. After adaptation the test object was visible, but, of course, not resolvable, to the unaided eyes.

The experimental procedure was essentially the same as in the work already described in Part I of this report, except for the details mentioned. Table V is, in part, a repetition of Table I, Part I, the values under the head " Angle, minutes " having been recomputed and being the angles subtended by one of the white elements of the test object, without magnification, at the distance here used, 81.65 metres.

TABLE V.

Stimulus No.	Width cm.	Angle min.	Stimulus No.	Width cm.	Angle min.	Stimulus No.	Width cm.	Angle min.
0	12.00	5.05	8	6.00	2.53	16	3.00	1.26
1	11.00	4.63	9	5.50	2.32	17	2.75	1.16
2	10.09	4.25	10	5.04	2.12	18	2.52	1.06
3	9.25	3.90	11	4.62	1.95	19	2.31	0.97
4	8.49	3.57	12	4.24	1.79	20	2.12	0.89
5	7.78	3.28	13	3.89	1.64	21	1.94	0.82
6	7.14	3.00	14	3.57	1.50	22	1.78	0.75
7	6.54	2.76	15	3.27	1.38	23	1.64	0.69
8	6.00	2.53	16	3.00	1.26	24	1.50	0.63

RESULTS.

The average times of observation, for right, wrong and indeterminate answers, and for each size of test object used are given in Tables VI, VII, and VIII. The mean deviations appear following the mean values. The numbers of right, wrong and indeterminate answers for the various conditions are also given, and in the last column the net frequency of right answers. In considering this last, it is to be remembered that in the previous work the wrong answers were at most very few, and they were left totally out of consideration. However, in the present work, in the case of one observer, they were numerous enough to be of importance, and it was not thought permissible to drop them altogether.

Obviously a wrong answer results from judgment in the absence of correct vision of the object. Such judgment (since the two positions of the object represent two possibilities) would, in the long run, result in equal numbers of right and wrong answers. Therefore, there is, in probability, a right answer given in the absence of correct vision for every wrong answer returned under the same conditions, and the net number of right answers, or the number of "truly" right answers is taken as the number of rights minus the number of wrongs. For this reason the frequencies in Tables VI, VII, and VIII are computed as the ratios of the net number of right answers ("right" minus "wrongs") to the total number of experiments.

In preparing Tables VI-A, VII-A, and VIII-A, three groups of experiments were omitted from consideration:

(1) Those in which wrong answers were returned, (2) an equal number of those in which right answers were given, selected

so as to have, each for each, as nearly as possible, equal times with the corresponding "wrongs," and (3) those which proved, when Chauvenet's criterion was applied, to have improbably long times of observation. It happened in a few cases that there were more wrongs than rights, in which event all of both classes were dropped without further consideration. Chauvenet's criterion was applied separately to the group of "rights" remaining after the second deletion, and to the group of experiments with indeterminate answer ("crosses"), under each experimental condition. The times, numbers and frequencies were then computed from the results remaining. The results given in these tables are also shown graphically in Figs. 7, 8, and 9. It is to be added here that the results were also plotted without omissions exactly as they came, and the plots were carefully examined and compared with the ones appearing here. It was found that they differed in no essential particular and that the discussion and conclusions following apply equally well in either case.

DISCUSSION.

Examination of Figs. 7, 8, and 9 shows several characteristics which apply equally well to each of the three observers. It appears, on examining the upper plots in the three figures, that for each observer vision was better (the frequency of right answers higher) when both eyes were used than when either eye was used alone. This is true in various degrees, somewhat doubtful in the case of P. W. C.

If we turn to the times of observation (lower plots) we find that where the test object is relatively large, that is, where the frequency of right answers is near to 100 per cent., the time required for observation with both eyes is shorter than with either eye alone. The three modes of observation (right, left, and both eyes) tend to show the same order of superiority with reference to time that they do with reference to frequency. Somewhere in the region where the frequency is 100 to 50 per cent. there is a stretch where the time of "right" observation with both eyes is about equal to that with either eye alone. It is in this stretch that the observations with doubtful answers begin to appear in significant numbers, and their average times are longer in the case of both eyes than with either one alone. Somewhat farther down

the scale of certainty even the right answers tend to be longer in coming, definitely in the case of S. M. S., Fig. 8, stimulus No. 10, and indicated in the case of W. W., Fig. 9, Nos. 10, 11, 12. Still farther down, where the frequency is very low, or where, we will say, observation is "certainly uncertain," a tendency is shown for even the doubtful answers to be rendered in less time when both eyes are used. This shows clearly in Fig. 8, stimulus No. 12, and is indicated in Fig. 7, No. 12.

SUMMARY.

Under illumination of twilight intensity, observation through a prism binocular showed the following differences between binocular and monocular use of the same:

(1) With binocular observation the threshold is somewhat lower than with monocular observation with the better of the two eyes alone.

(2) When the test object is of such size that the judgments are preponderantly correct, the decision of the observer is arrived at in shorter time with binocular observation than with monocular.

(3) There seems to be reason to believe that this is also true in a negative sense. When the test object is very small and all or nearly all the judgments are indeterminate these also are to some extent rendered in shorter time with binocular observation than with monocular.

(4) With sizes of test object such that both right and indeterminate judgments appear in large numbers, the tendency is to spend more time in binocular observation than in monocular. This appears as an outspoken difference in time in the case of the indeterminate judgments, and in the case of the right judgments as a tendency for the time to become equal to or greater than the monocular time as the size of the test object is reduced. Compare with item (2) above.

It would seem, then, not only that vision with the glass is better and quicker with two eyes than with one, but also that the subject is readier or more willing, for some reason, to prolong his observations in the uncertain cases when he is observing binocularly.

TABLE VI.

Summary of Results.

A Tabulation of the Number of Right (*R*), Wrong (*W*), and Indeterminate (*X*) Answers for Each Size of Stimulus Presented; the Average Length of Time Required for Each of the Above Sets of Answers, Together with Their Mean Deviations; and the Statistical Frequency of the Occurrence of Right Answers.

Observer P. W. C.

Stimulus Number	Time in seconds			Number			Frequency
	R	*W*	*X*	*R*	*W*	*X*	$\frac{R-W}{R+W+X}$
			Both eyes.				
7	8.2 ± 3.1	.....	.....	46	0	0	1.000
8	16.3 ± 10.2	.....	92.0 ± 0	45	0	1	0.978
9	21.8 ± 14.9	.....	47.4 ± 15.1	34	0	12	0.739
10	33.3 ± 18.8	.....	62.7 ± 17.4	22	0	24	0.478
11	30.3 ± 11.5	.....	52.8 ± 17.4	9	0	37	0.195
12	51.0 ± 0	.....	48.7 ± 19.4	1	0	45	0.022
13	24.0 ± 0	.....	41.6 ± 12.3	1	0	45	0.022
			Left eye.				
5	5.8 ± 1.8	.....	.....	46	0	0	1.000
6	10.6 ± 4.9	.....	.....	46	0	0	1.000
7	14.5 ± 7.8	.....	65.8 ± 15.1	42	0	4	0.913
8	20.2 ± 11.3	.....	64.0 ± 23.7	40	0	6	0.870
9	26.9 ± 13.7	98.0 ± 0	53.9 ± 13.6	26	1	19	0.543
10	56.3 ± 20.6	.....	51.7 ± 15.6	14	0	32	0.304
11	35.5 ± 9.5	76.5 ± 67.5	48.9 ± 12.6	2	2	42	0.000
12	.....	.....	48.1 ± 15.8	0	0	42	0.000
			Right eye.				
6	8.2 ± 3.5	.....	.....	46	0	0	1.000
7	11.8 ± 6.3	.....	.....	46	0	0	1.000
8	18.7 ± 10.2	.....	61.5 ± 6.5	44	0	2	0.956
9	31.3 ± 16.2	48.0 ± 0	60.4 ± 14.7	34	1	11	0.717
10	33.9 ± 11.2	.....	48.6 ± 16.2	18	0	28	0.391
11	38.8 ± 22.3	.....	47.6 ± 17.2	12	0	34	0.261
12	.....	.....	50.8 ± 14.5	0	0	44	0.000

TABLE VI–A.

Corrected Results.

A Summary Similar to Table VI, but with Wrong Answers and an Equal Number of Right Answers with Corresponding Times Omitted, and Huge Time-values Eliminated by the Application of Chauvenet's Criterion.

Observer P. W. C.

Stimulus Number	Time in seconds		Number		Frequency $\frac{R}{R+X}$
	R	X	R	X	
		Both eyes.			
7	6.9 ± 2.0	.....	41	0	1.000
8	9.7 ± 3.1	92.0 ± 0	35	1	0.972
9	14.6 ± 6.8	38.8 ± 7.6	29	10	0.744
10	33.3 ± 18.8	62.7 ± 17.4	22	24	0.478
11	30.3 ± 11.5	51.1 ± 16.0	9	36	0.200
12	51.0 ± 0	48.6 ± 19.4	1	45	0.022
13	.....	41.6 ± 12.3	0	45	0.000
		Left eye.			
5	5.0 ± 2.5	.....	40	0	1.000
6	7.9 ± 2.2	.....	38	0	1.000
7	9.7 ± 2.4	65.8 ± 15.1	34	4	0.895
8	16.3 ± 7.2	64.0 ± 23.7	37	6	0.860
9	22.4 ± 10.0	53.9 ± 13.6	23	19	0.548
10	56.3 ± 20.6	49.6 ± 14.4	14	31	0.311
11	.....	42.5 ± 6.9	0	35	0.000
12	.....	48.1 ± 15.8	0	42	0.000
		Right eye.			
6	6.5 ± 1.8	.....	39	0	1.000
7	8.3 ± 2.4	.....	39	0	1.000
8	15.0 ± 6.2	61.5 ± 6.5	39	2	0.951
9	30.9 ± 16.1	60.4 ± 14.7	33	11	0.750
10	33.9 ± 11.2	48.6 ± 16.2	18	28	0.391
11	38.8 ± 22.3	47.6 ± 17.2	12	34	0.261
12	.....	49.5 ± 13.6	0	43	0.000

TABLE VII.

Summary of Results.

A Tabulation of the Number of Right (*R*), Wrong (*W*), and Indeterminate (*X*) Answers for Each Size of Stimulus Presented; the Average Length of Time Required for Each of the Above Sets of Answers, Together with their Mean Deviations; and the Statistical Frequency of the Occurrence of Right Answers.

Observer S. M. S.

Stimulus Number	Time in seconds			Number			Frequency $\frac{R-W}{R+W+X}$
	R	*W*	*X*	*R*	*W*	*X*	
			Both eyes.				
5	4.4 ± 1.1	.....	.....	24	0	0	1.000
6	7.9 ± 4.6	.....	.....	56	0	0	1.000
7	8.7 ± 4.0	.....	25.0 ± 0	55	0	1	0.982
8	20.3 ± 11.9	3 ± 0	38.6 ± 13.4	48	1	8	0.825
9	23.2 ± 15.0	.....	39.4 ± 16.8	27	0	29	0.482
10	35.8 ± 15.8	.....	32.7 ± 11.8	11	0	45	0.196
11	40.0 ± 0	36 ± 0	31.0 ± 12.7	1	1	54	0.000
12	.....	.....	25.7 ± 8.6	0	0	50	0.000
			Left eye.				
5	7.3 ± 3.3	.....	.....	56	0	0	1.000
6	11.4 ± 6.8	.....	.....	56	0	0	1.000
7	16.8 ± 8.8	.....	57.0 ± 23.3	53	0	3	0.946
8	20.3 ± 10.4	.....	38.6 ± 9.7	43	0	13	0.768
9	22.9 ± 12.5	13 ± 0	32.6 ± 12.8	22	1	33	0.375
10	25.2 ± 13.8	.....	27.6 ± 9.3	6	0	50	0.107
11	26.0 ± 3.0	.....	29.6 ± 11.5	2	0	54	0.036
12	.....	.....	33.3 ± 11.1	0	0	20	0.000
			Right eye.				
5	6.5 ± 2.8	.....	5.0 ± 0	55	0	1	0.982
6	9.2 ± 4.5	.....	.....	56	0	0	1.000
7	15.3 ± 10.0	.....	25.3 ± 4.4	53	0	3	0.946
8	19.3 ± 9.5	.....	39.8 ± 15.4	44	0	12	0.786
9	24.0 ± 13.7	.....	32.5 ± 13.8	23	0	33	0.410
10	27.4 ± 8.8	19 ± 0	30.3 ± 12.3	7	1	48	0.107
11	24.0 ± 10.7	.....	26.3 ± 8.7	3	0	53	0.054
12	46.0 ± 0	.....	31.9 ± 13.2	1	0	21	0.048

TABLE VII–A.

Corrected Results.

A Summary Similar to Table VII, but with Wrong Answers and an Equal Number of Right Answers with Corresponding Times Omitted, and Huge Time-values Eliminated by the Application of Chauvenet's Criterion.

Observer S. M. S.

Stimulus Number	Time in seconds		Number		Frequency
	R	*X*	*R*	*X*	$\frac{R}{R+X}$
		Both eyes.			
5	4.0 ± 0.7	.....	22	0	1.000
6	5.4 ± 1.8	.....	47	0	1.000
7	7.0 ± 2.2	25.0 ± 0	49	1	0.980
8	17.9 ± 9.4	38.6 ± 13.4	44	8	0.846
9	18.3 ± 9.7	33.2 ± 11.6	25	26	0.490
10	35.8 ± 15.8	32.7 ± 11.8	11	45	0.196
11	.....	27.2 ± 9.0	0	50	0.000
12	.....	24.2 ± 4.9	0	48	0.000
		Left eye.			
5	6.8 ± 2.8	.....	54	0	1.000
6	8.5 ± 3.9	.....	49	0	1.000
7	14.6 ± 6.6	57.0 ± 23.3	50	3	0.943
8	14.6 ± 5.3	38.6 ± 9.7	36	13	0.735
9	21.4 ± 10.8	27.5 ± 7.5	20	30	0.400
10	25.2 ± 13.8	27.0 ± 8.8	6	49	0.109
11	26.0 ± 3.0	27.4 ± 9.4	2	52	0.037
12	.....	33.3 ± 11.1	0	20	0.000
		Right eye.			
5	5.2 ± 1.3	5.0 ± 0	48	1	0.980
6	7.3 ± 2.4	.....	49	0	1.000
7	9.5 ± 3.2	25.3 ± 4.4	44	3	0.936
8	15.0 ± 5.2	39.8 ± 15.4	38	12	0.760
9	16.9 ± 4.9	26.5 ± 7.2	21	30	0.412
10	28.7 ± 9.2	25.8 ± 7.6	6	43	0.122
11	24.0 ± 10.7	25.0 ± 7.4	3	51	0.056
12	46.0 ± 0	31.9 ± 13.2	1	21	0.045

TABLE VIII.

Summary of Results.

A Tabulation of the Number of Right (R), Wrong (W) and Indeterminate (X) Answers for Each Size of Stimulus Presented; the Average Length of Time Required for Each of the Above Sets of Answers, Together with their Mean Deviations; and the Statistical Frequency of the Occurrence of Right Answers.

Observer W. W.

Stimulus Number	Time in seconds			Number			Frequency $\frac{R-W}{R+W+X}$
	R	W	X	R	W	X	
			Both eyes.				
7	6.6 ± 2.0	.....	.....	52	0	0	1.000
8	8.0 ± 3.0	.....	.....	52	0	0	1.000
9	12.9 ± 6.4	.....	32.0 ± 0	51	0	1	0.981
10	23.7 ± 12.1	.....	50.9 ± 6.9	41	0	11	0.789
11	26.7 ± 14.5	.....	53.6 ± 16.9	27	0	25	0.519
12	29.6 ± 11.3	33.0 ± 16.0	53.8 ± 14.0	17	2	33	0.289
13	50.2 ± 11.4	38.3 ± 12.0	51.4 ± 16.1	5	6	41	0.000
14	39.3 ± 16.4	41.4 ± 20.5	49.7 ± 14.2	3	5	32	0.000
			Left eye.				
6	5.7 ± 1.6	.....	35.0 ± 0	51	0	1	0.981
7	9.3 ± 4.7	.....	35.0 ± 0	51	0	1	0.981
8	10.3 ± 3.6	.....	35.4 ± 9.6	45	0	7	0.865
9	18.6 ± 11.1	21.0 ± 0	44.1 ± 12.3	41	1	10	0.770
10	17.9 ± 6.9	.....	37.1 ± 12.0	28	0	24	0.538
11	26.9 ± 13.8	38.0 ± 28.0	37.2 ± 10.9	15	2	35	0.250
12	29.5 ± 9.0	24.5 ± 16.3	40.3 ± 11.8	6	6	40	0.000
13	17.0 ± 0	56.0 ± 10.0	40.8 ± 11.6	1	3	29	0.000
			Right eye.				
7	7.5 ± 2.3	.....	.....	52	0	0	1.000
8	12.3 ± 5.5	.....	.....	52	0	0	1.000
9	16.9 ± 8.3	.....	37.0 ± 14.0	49	0	3	0.942
10	21.9 ± 9.8	.....	40.4 ± 10.0	33	0	19	0.635
11	28.7 ± 12.6	36.0 ± 20.0	41.5 ± 14.2	18	3	31	0.288
12	32.4 ± 15.3	18.7 ± 6.0	43.0 ± 11.2	7	7	38	0.000
13	38.0 ± 8.0	32.8 ± 15.2	42.2 ± 11.5	2	4	40	0.000
14	.....	37.6 ± 23.1	38.7 ± 9.1	0	5	33	0.000

TABLE VIII–A.

Corrected Results.

A Summary Similar to Table VIII, but with Wrong Answers and an Equal Number of Right Answers with Corresponding Times Omitted, and Huge Time-values Eliminated by the Application of Chauvenet's Criterion.

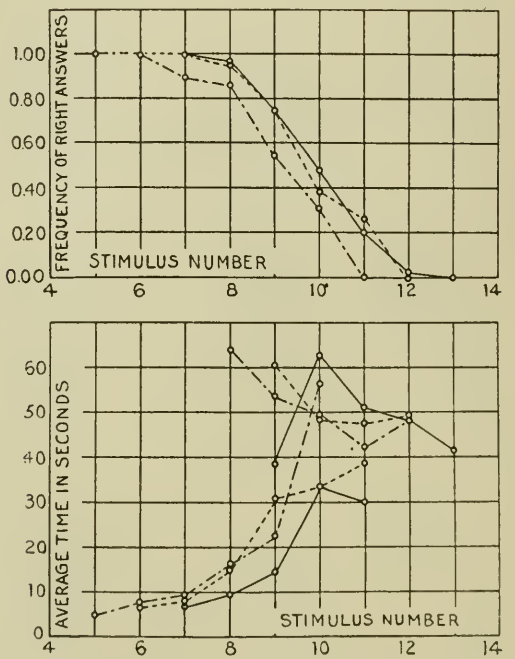
Observer W. W.

Stimulus Number	Time in seconds		Number		Frequency
	R	*X*	*R*	*X*	$\frac{R}{R+X}$
		Both eyes.			
7	5.8 ± 1.3	.....	46	0	1.000
8	6.6 ± 1.6	.....	45	0	1.000
9	9.8 ± 3.3	32.0 ± 0	44	1	0.978
10	21.8 ± 10.1	48.3 ± 6.0	40	10	0.800
11	24.4 ± 12.2	49.4 ± 14.0	26	23	0.530
12	29.1 ± 10.5	53.8 ± 14.0	15	33	0.312
13	.....	51.4 ± 16.1	0	41	0.000
14	.....	46.7 ± 11.6	0	30	0.000
		Left eye.			
6	5.0 ± 0.9	35.0 ± 0	47	1	0.979
7	7.6 ± 2.7	35.0 ± 0	47	1	0.979
8	9.3 ± 2.7	35.4 ± 9.6	42	7	0.857
9	16.1 ± 8.9	44.1 ± 12.3	38	10	0.792
10	14.0 ± 3.4	37.1 ± 12.0	23	24	0.489
11	25.2 ± 11.5	35.8 ± 9.8	13	34	0.276
12	.....	37.2 ± 9.3	0	37	0.000
13	.....	39.1 ± 9.8	0	28	0.000
		Right eye.			
7	7.5 ± 2.3	.....	52	0	1.000
8	9.5 ± 2.5	.....	45	0	1.000
9	13.4 ± 4.6	37.0 ± 14.0	43	3	0.935
10	21.9 ± 9.7	36.1 ± 6.6	33	16	0.674
11	28.0 ± 11.7	39.7 ± 13.0	15	30	0.333
12	.....	41.4 ± 9.6	0	36	0.000
13	.....	39.0 ± 8.6	0	37	0.000
14	.....	38.7 ± 9.1	0	33	0.000

COMPARISON OF RESULTS—DAYLIGHT AND TWILIGHT.

The absolute values of the thresholds for the various conditions may be interpolated from the upper plots of Figs. 3, 4, and 5 of Part I and Figs. 7, 8, and 9 as the point on the stimulus scale at which the right judgments are 50 per cent. of the whole number of experiments. The values for binocular vision will be sufficient for the present purpose, and they are stated in Table IX. Re-

FIG 7.



BOTH EYES— LEFT EYE—·—·— RIGHT EYE-----
CORRECTED RESULTS OBSERVER P.W.C.

ferring to Table I, Part I, or to Table V, as the case may be, gives the corresponding angle, which, multiplied by the magnification factor 6, gives the visual angle. The reciprocal of this angle in minutes is visual acuity on the Snellen scale.

It will be seen from the table that under daylight conditions the three observers agreed quite closely in the value of their binocular sensitivity, while under the dim light the variation is

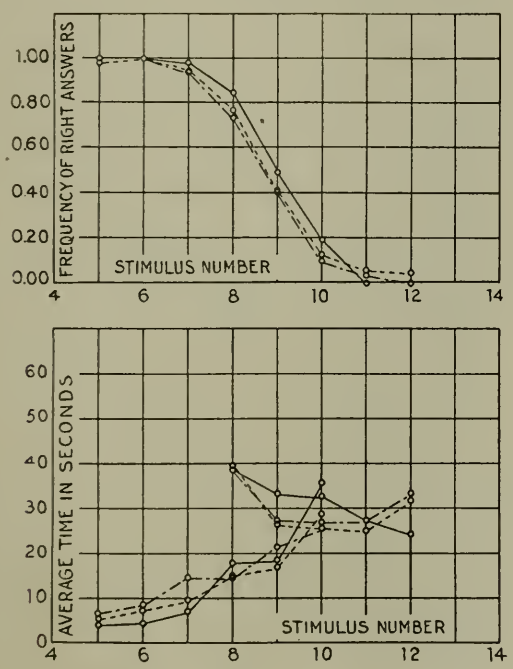
relatively much larger, although in either case the deviation is not wide. The mean acuity for the daylight condition is, of course, much the larger, by a ratio of 15.6 to 1.

TABLE IX.

The Binocular Threshold Value and Visual Acuity for Daylight and Twilight Conditions.

Conditions	Observer	Stimulus number	Angle min.	X 6	Visual acuity (Snellen)
Daylight Distance 956 m	P. W. C.	13.3	0.135	0.810	1.23
	G. H.	13.5	.133	.798	1.25
	W. W.	13.1	.138	.828	1.21
Twilight Distance 81.65 m	P. W. C.	9.9	2.14	12.84	0.078
	S. M. S.	9.0	2.32	13.92	0.072
	W. W.	11.0	1.93	11.58	0.086

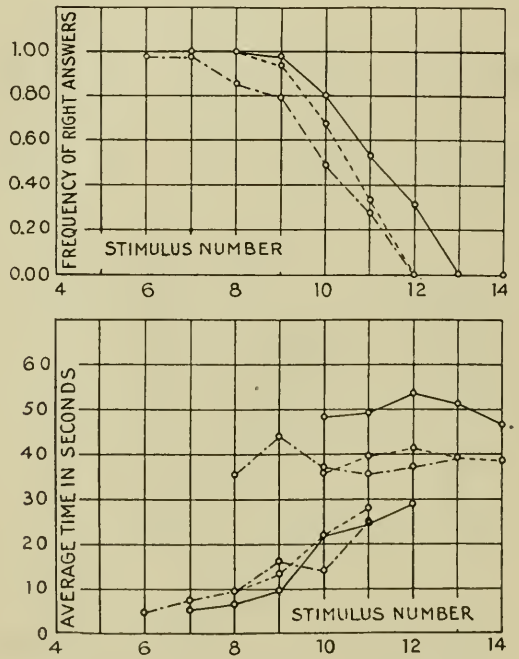
FIG 8.



BOTH EYES —— LEFT EYE —·—·— RIGHT EYE -----
CORRECTED RESULTS. OBSERVER S.M.S.

The object just resolvable by unaided vision under daylight condition is only 6 times the size of the object just resolvable through the 6-power glass under the same conditions, and probably less than this by a substantial amount, because of the absorption of light by the glass parts and the inevitable tremor of the glass; the latter especially, to no inconsiderable degree, reduces the effectiveness of the magnification. The object just resolvable

FIG 9.



BOTH EYES —— LEFT EYE —·—·— RIGHT EYE - - - -
CORRECTED RESULTS. OBSERVER W.W.

under twilight conditions is, therefore, not less than 2.6 (15.6/6) times as large as is necessary for it to be seen by unaided vision in full daylight. The problem of vision through a glass under twilight conditions is then, in point of the visual magnitudes considered, a wholly different one from that under full daylight, in several respects:

(1) The object of vision will, no doubt, be of a different practical class in the two cases.

(2) The much lower resolving power of the eye and hence the much larger visual angles considered under twilight conditions, no doubt, could be shown to make certain inherent disadvantages of the glass of less importance. In particular, it is quite probable that a higher magnifying power could be used, before the benefit of the increased magnification would be fully offset by the increase in the effect of unsteadiness thereby engendered; and also that higher errors in the optical parts, both spherical and chromatic, would be tolerable, and hence objectives of larger diameter available with a corresponding increase in the emergence pupil (up to the maximal diameter of the eye pupil) and in the amount of light. The present work, having been conducted in the two cases with the identical instrument, does not show what the relative visual effectiveness might become with two different instruments of optimal design for the respective conditions; nor does it attempt to make an estimate of the relative practical value of the glass under the two conditions.

In discussing the time values it was stated in Part I of this report, as applying to that portion of the work, that the slightly larger frequency of right judgments in binocular vision was offset or at least rendered indecisive as experimental evidence by the greater time required for observations. To find out whether, on the whole, the increased time was disproportionately large as compared with the difference in the certainty of vision the data were treated in a different way, and the results of this computation, applied both to the daylight and the twilight data, are set down in Table X.

For each observer the region of the stimulus scale was selected which included practically all of the stimuli upon which both right and doubtful answers were returned. For each mode of observation identical stimuli were chosen and the number of experiments on each stimulus is the same. The figures in the table apply in every case to all of the experiments, so that each section of the table shows the "performance" of the observer with respect to identical groups of varied stimuli in the three modes of observation. The last column of figures gives the results obtained, in each case, by dividing the aggregate time of observa-

tion for all experiments by the net number of right judgments ("rights" minus "wrongs") and is, therefore, a measure of the efficiency—or rather of the inefficiency—of the particular mode of observation.

Under full daylight, it will be remembered, observer P. W. C. gave distinctly poorer results in every respect with binocular observation. For the other two it is shown in the last column of Table X that the increased binocular frequency was purchased by relatively greater expenditure of time—definitely in the case of W. W. (as 42.7 to 46.3), and perhaps doubtfully in the case of G. H. (as 35.0 to 35.8). The "efficiencies" of binocular vision, taking the results from the better eye as a base, are for full daylight: for P. W. C., 83.5 per cent.; for W. W., 92 per cent.; and for G. H., 98 per cent.

In the case of twilight vision the figures tell a different story, for while the whole time of binocular vision is either less or very slightly more than in the better of the two monocular cases, the last column shows that for all three observers the total time is smaller, as compared with the number of right answers. The "efficiencies" of binocular observation for twilight conditions, on the same basis as in the last paragraph, are: for P. W. C., 108 per cent.; for W. W., 123 per cent.; and for S. M.S., 104 per cent.

It is perhaps taking too much for granted to assume, as the foregoing does at least by implication, that increased time spent in observation would lead to a proportionate increase in the frequency of correct vision. In all probability it would not, and it is not possible to state the direction in which such an assumption would err. It would seem, however, that this manner of comparison shows pretty clearly an advantage of the binocular glass over the monocular in its use in light of low intensities under conditions comparable to those of these experiments. It would also seem quite permissible to accept the foregoing method of interpreting the results as supplementary to the more detailed treatment which has gone before, especially when the last-mentioned (as in the daylight results) renders an ambiguous verdict.

TABLE X.

Average Times of Observations for Comparing Binocular with Monocular and Daylight with Twilight Observations.

		Number		$R-W$ Per cent.	Average time		Total time per $(R-W)$
		$R-W$	All		All	$(R-W)$	
Full Daylight.							
P. W. C.,	Both	148	246	60.2	25.7	16.0	42.7
Stimuli,	Left	166	246	67.5	24.1	15.9	35.7
No. 10–No. 15,	Right	105	246	42.7	28.2	17.2	66.0
W. W.,	Both	150	252	59.5	27.6	20.0	46.3
Stimuli,	Right	145	252	57.5	24.6	18.7	42.7
No. 10–No. 15,	Left	114	252	45.2	26.8	21.1	59.1
G. H.,	Both	153	246	62.2	22.2	16.0	35.8
Stimuli,	Left	149	246	60.6	21.2	14.4	35.0
No. 10–No. 15,	Right	112	246	45.5	23.9	18.2	52.6
Twilight (0.0012 Foot-candle)							
P. W. C.,	Both	157	276	56.9	33.4	18.5	58.7
Stimuli,	Right	153	276	55.4	35.0	22.6	63.1
No. 7–No. 12,	Left	121	276	43.8	39.2	23.4	89.4
W. W.,	Both	186	260	71.5	27.1	17.2	37.9
Stimuli,	Right	149	260	57.3	26.8	17.5	46.8
No. 8–No. 12,	Left	126	260	48.5	27.1	16.1	55.9
S. M. S.,	Both	195	336	58.0	22.6	14.8	39.0
Stimuli,	Right	185	336	55.1	22.3	16.1	40.5
No. 6–No. 11,	Left	181	336	53.9	23.4	17.1	43.4

(To be concluded.)

Important Vegetable Acids from Benzene. (*Amer. Chem. Soc. News Service,* Bulletin 252.)—Announcement has just been made by John M. Weiss and C. R. Downs, inventors and patentees, of a method by which tartaric, citric, lactic and succinic acids can be prepared from benzene at prices capable of competition with the natural products. The starting point is the production of maleic acid by the joint action of air and benzene under the influence of a catalyst, and from this acid those above mentioned can be obtained. Maleic acid has long been known as a natural product but its extraction has been too costly to consider it as a raw material for any commercial article. The synthetic production of tartaric acid will meet the possible diminution of the natural supply due to the cessation of wine-making in this country. The United States has been producing about ten million pounds of cream of tartar per year and about a million pounds of tartaric acid. H .L.

The Relation Between Uranium and Radium. SODDY. (*Phil. Mag.,* October, 1919, p. 483.)—The growth of radium in three kilograms of uranium has been studied for a period of ten years and again in .4 kilogram (note = four-tenths kilogram) for more than twelve years. In the larger quantity the total radium formed amounts to 242×10^{-12} gr. A quantity of radium as small as 10^{-12} gr. can be measured accurately. In both investigations the mass of radium formed is proportional to the square of the time during which it has been forming, thus in seven years 49 times as much will be developed as in one year.

G. F. S.

Hydro-electric Survey of India. (*Nature,* December 4, 1919.)—In this matter India is much behind other parts of the British Empire. Canada has installations for 148 watts per inhabitant. The corresponding number for Australia is 62; for South Africa, 57; for the British Isles, 33; while for India it is less than one. The total brake-horsepower of all kinds in India is 1,153,638 plus what is developed in some collieries and rice mills. Hydro-electric development is complicated by the uneven distribution of rainfall throughout the year, and by the holding of mountain regions with water power by uncivilized tribes.

G. F. S.

Competitive Exhibition of Machines and Materials Used in the Building Trades. (*La Nature,* December 13, 1919.)—At the Lyons Fair of March, 1920, there will be a competition between such machines, materials and products as represent progress in advance of what existed before the war. Machines will run under working conditions.

Such an exhibition will be timely in view of the hundreds of thousands of buildings destroyed in France as a result of the invasion by the Huns.

At this fair in 1919 the United States was represented on the program of speakers by Professor Fletcher (Pennsylvania State College) and by other members of the Faculty of the A. E. F. University at Beaune.

G. F. S.

Production of Iron in Italy.—According to the Italian Metallurgical Association, the ores obtained in Italy are about exhausted. Hitherto the chief source of iron ore has been in Elba. The cost of mining is, however, continuously on the increase, as the deposits are under the sea. Under the urge of the war vigorous search was made for new bodies of ore. At Val di Cogne, near the French border, six million tons were discovered, and in Sardinia an equally important deposit was located. These new resources cannot do more than postpone Italy's dependence for her iron upon other nations.

G. F. S.

BRANNERITE, A NEW URANIUM MINERAL.*

BY

FRANK L. HESS, A.B., and ROGER C. WELLS, Ph.D.

United States Geological Survey.

In 1915 S. M. Ballard sent to one of the writers a highly radioactive mineral that had been obtained from gold placers worked by Henry Sturkey in Stanley Basin in the central part of Idaho. Later other material was sent to the Survey by Mr. Sturkey. Mr. Sturkey's placer is near the head of Kelley Gulch, said to be in granite cut by pegmatites, and it is in the pegmatites that the source of the mineral is probably to be found.

In 1916 Robert N. Bell published a half-tone of a radiograph [1] made with the mineral by A. G. Van Eman, who thought it to be euxenite, with which it is related in composition and which it resembles in color and texture.

The mineral received is in grains, part of which are prisms and most of which show a prismatic tendency (see Fig. 1). They are a brownish yellow on the outside but the visible weathering has extended to a depth not exceeding the thickness of paper. Inside they are brilliant black, with a choncoidal fracture and no sign of cleavage. Polished specimens examined under reflected light show the mineral to be remarkably homogeneous. It is, however, traversed by minute cracks that are in part filled by quartz that undoubtedly accounts for the SiO_2 in the analysis. Although to the eye the mineral is an opaque black, under the microscope very thin chips allow sufficient yellowish green light to pass to make possible optical measurements. The streak is a dark greenish brown. The hardness is about 4.5 as the mineral will scratch apatite but will not scratch orthoclase.

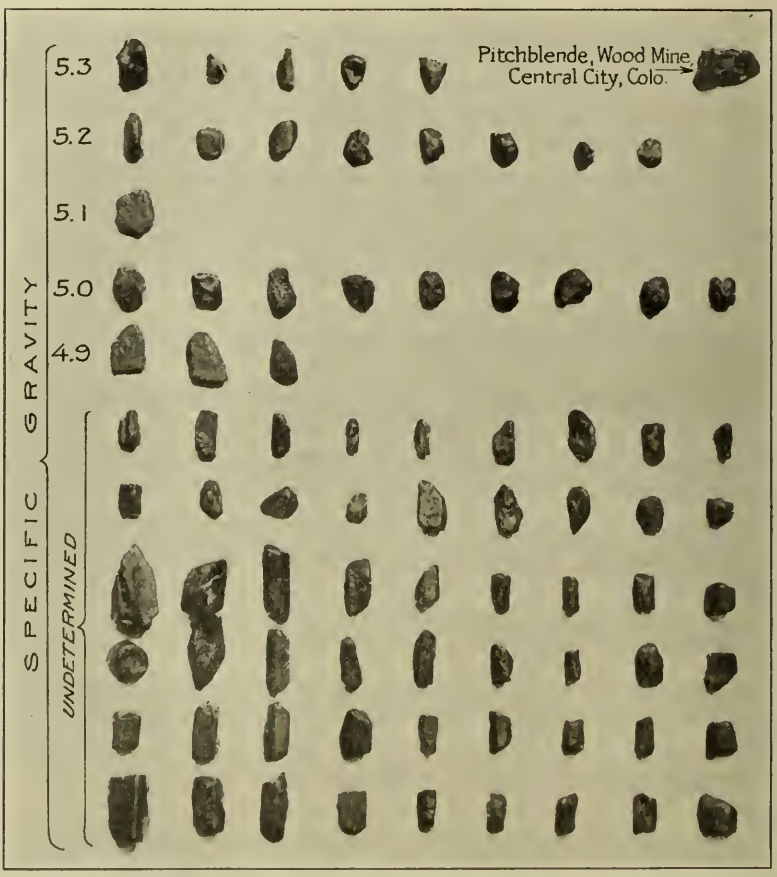
The crystals are not perfect enough to allow a determination of the crystal form, but their shapes suggest that they may be orthorhombic or tetragonal. However, E. S. Larsen determined it to be isotropic with an index of $n_{Li} = 2.26 \pm 0.02$ and $n_{Na} = 2.30 \pm 0.02$. It seems probable that it is an isometric paramorph after either a tetragonal or an orthorhombic form as many of the

* Published by permission of the Director of the United States Geological Survey.

[1] Sixteenth Ann. Rept. Mine Inspector of Idaho (1915), Boise, pp. 29, 30.

complex pegmatitic uranium minerals seem to be. It will be noted in the tables given on other pages of this article that all but one of the minerals (hielmite) are isotropic. Yttrocrasite shows birefringent particles and is probably a mixture. Also like

FIG. 1.

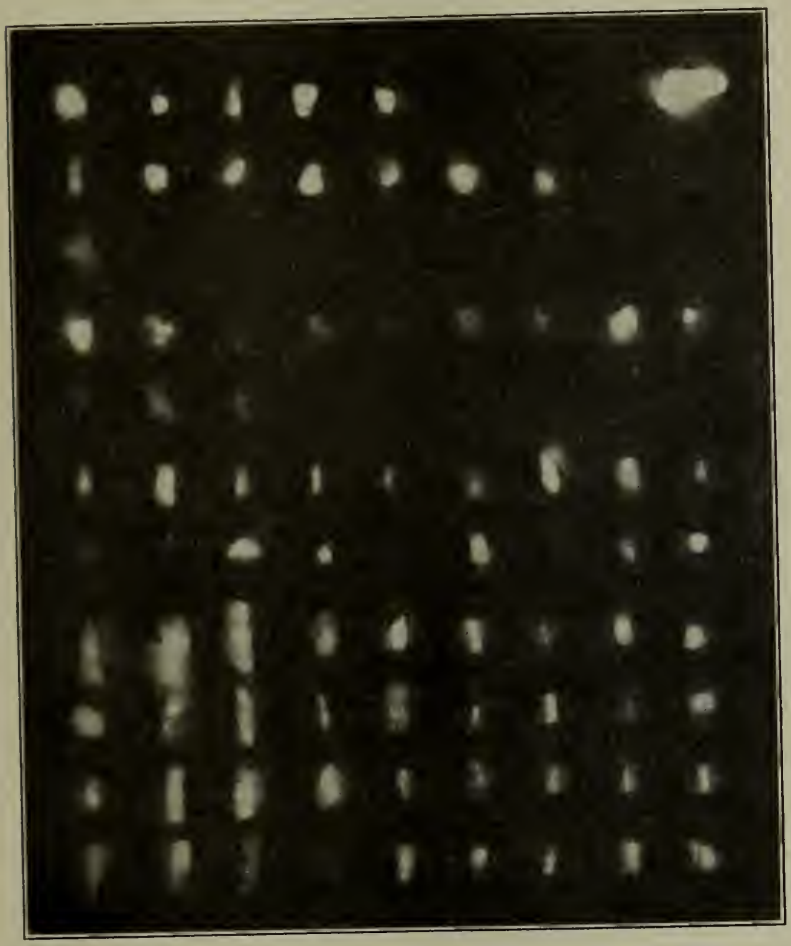


Brannerite pebbles and a piece of pitchblende mounted on a card to test comparative radioactivity. Slightly reduced. See figure on opposite page.

nearly all of the complex pegmatitic minerals, the new mineral is variable in composition and the specific gravity of the specimens tested ranged from 4.5 to 5.43, as determined with the Joly balance. The specimens analyzed had a specific gravity of 5.42 (by pyknometer).

The radioactivity of the specimens of different specific gravities showed slight differences as tested by the exposure of a

FIG. 2.



Radiograph made by the minerals shown in figure 1. They were mounted on thin cardboard which was laid on the sensitive film of a photographic plate for 48 hours. A print was photographed through a prism in order to make comparison easier.

photographic plate. Those having the highest specific gravity appeared most active (see Fig. 2). The material was not tested in an electroscope. Attention may be called to the advantages of making a radiograph of various specimens in a case of this

sort before proceeding with the analysis, as it may be seen from Fig. 2 that some of the pieces were comparatively inactive, and pieces with a like content of uranium or thorium, or both may be readily selected. Two of the least active pieces from the seventh row (Fig. 2) gave on analysis 35.0 per cent. TiO_2 compared with 39.0 per cent. in the best material.

If in quantity the mineral would be of value as a source of radium, but probably only a few pounds could be obtained even at a prohibitive cost.

CHEMICAL ANALYSIS.

Our thanks are due to Mr. W. C. Wheeler for preliminary chemical determinations on the mineral. Mr. Wheeler established the presence of uranium and suggested the separation of titanium and uranium by hydrolysis, as finally carried out.

The mineral is slowly decomposed by treatment with concentrated sulfuric acid, or by hydrofluoric and sulfuric acids. It is more convenient, however, to bring it into solution by gentle fusion with acid sodium sulfate. On dissolving the melt in cold water, or dilute sulfuric acid, there remains a small residue consisting of silica, unattacked mineral, and sulfates of lead, barium and strontium, which was analyzed separately.

Various methods of analysis were tried, using principally the acid sulfate solution, but the unusual association of elements made the analysis largely a process of successive approximations. Each precipitate obtained was tested for impurities and if an admixture was found the method of analysis was modified accordingly.

It was thought at one time that the ammonium carbonate treatment could be relied on to separate the main constituents, uranium and titanium, but so much titanium was carried into the filtrate with the uranium in this process that it was decided to separate the titanium by hydrolysis. The precipitate and filtrate were then further analyzed separately.

For the hydrolytic separation of titanium the sulfate solution was treated with hydrogen sulfide, neutralized, freed from hydrogen sulfide with a stream of carbon dioxide, and finally diluted and boiled after the addition of considerable ammonium sulfate.[2]

In one analysis 3.1 per cent. of rare earths was found in the titanium separated as described and 5.0 per cent. in the uranium

[2] Hillebrand, W. F., U. S. Geol. Survey, Bull. 422, 137 (1910).

portion. In another analysis the total rare earths separated directly, first as fluorides and finally as oxalates, amounted to 8.0 per cent.

The filtrate from the titanium was precipitated twice with ammonium hydroxide, leaving calcium in solution. The hydroxides were dissolved in hydrochloric acid, evaporated nearly to dryness, taken up in hydrofluoric acid and the rare earths filtered off. After removing hydrofluoric acid with sulfuric acid, precipitating with ammonia, and dissolving the hydroxides in nitric acid, the remaining elements, chiefly uranium, were subjected to the ammonium carbonate treatment and uranium was finally separated and weighed as pyrophosphate.

The stage of oxidation of the uranium in the mineral was determined separately by decomposition with dilute sulfuric acid in a closed glass tube containing carbon dioxide at 225° C. and subsequent titration with potassium permanganate. It was assumed in calculating the proportion of UO_2 that all the iron of the mineral was in the ferrous condition. The only ground for this assumption is the fact that iron is more easily reduced than uranium, so that the existence of any uranous oxide would imply the absence of ferric oxide. However, the state of oxidation of the iron cannot be regarded as determined. The coating on the grains contained some ferric oxide which could only be removed by carefully chipping off the exterior and selecting the jet black pieces. A determination of iron as Fe_2O_3 on unselected material gave 3.7 per cent., whereas the value obtained on the best selected material was 3.0 per cent., or 2.7 per cent. FeO. Iron seems to be an essential constitutent of the mineral. In the extended analysis iron had to be determined in the titanium portion, in the ammonium carbonate precipitate, and in the uranium precipitate.

Thorium was determined in the mixture of rare earths by the sodium thiosulfate method. The ignited oxide was white, and pure as far as could be determined. The yttrium earths were estimated by their solubility in a solution of sodium sulfate. They were a buff color after ignition and gave by conversion of the oxides to sulfates, an average atomic weight of 151, a weight so great that probably erbium or ytterbium or both are present. Lack of time prevented a thorough investigation of the rare earths. No cerium earths could be detected. Water and carbon dioxide were weighed in absorption tubes after heating the min-

eral in a boat in a hard glass tube in a current of dry air. A small correction was applied based on the results of blank determinations run similarly. No magnesium, tin, tungsten, tantalum, columbium, molybdenum, vanadium, copper, or fluorine could be detected.

An attempt was made to heat the mineral, mixed with carbon, in a stream of chlorine and make a fractional condensation of the volatile chlorides. A complete separation of the uranium and titanium was not accomplished, but the non-volatile residue in the boat was found to contain calcium, rare earths chiefly of the yttrium group, iron, and a little uranium.

An attempt was also made to detect helium but without success. On heating 5 grammes of the mineral with acid sodium sulfate in a vacuum a few cubic centimetres of gas were obtained —largely sulfur dioxide, which was probably generated by the action of the UO_2 on the sulfuric acid. Nearly all of the gas was soluble in a solution of sodium hydroxide and what remained gave only nitrogen lines, as far as could be determined, when examined in a Pluecker tube.

The various determinations led to the following results:

Composition of the Mineral from Stanley Basin.

(R. C. Wells, analyst.)

	Per cent.	Molecular values.
SiO_2	.6	.010
TiO_2	39.0	.488
FeO	2.9	.040
CaO	2.9	.052
UO_2	10.3	.038
UO_3	33.5	.116
ThO_2	4.1	.015
Ce_2O_3	none	
Yt_2O_3, etc.[1]	3.9	.011
ZrO_2	.2	.001
PbO	.2	.001
BaO	.3	.002
SrO	.1	.001
H_2O	2.0	.111
CO_2	.2	.005
Fe_2O_3, Al_2O_3, P_2O_5	trace	
	100.2	

Specific gravity, 5.42.

[1] Average molecular weight 350

CALCULATION OF FORMULA

The following combinations in molecular values seem logical:

FeO	.040	UO_2	.038	CO_2	.005
CaO	.052	ThO_2	.015	SiO_2	.010
BaO	.002	ZrO_2	.002	TiO_2	.488
SrO	.001		—		—
PbO	.001		.055		.503
	.096				

This leaves $Yt_2O_3 = 0.011$, $UO_3 = .116$, and $H_2O = .111$ ungrouped. On this basis the mineral may be simplified to:

RO	.096		8.7
Yt_2O_3	.011		1.0
RO_2	.055	or	5.0
UO_3	.116		10.5
TiO_2	.503		45.7
H_2O	.111		10.1

Without any further combination this yields the following approximate formula:

$$9\ RO.\ \ Yt_2O_3.\ \ 5\ RO_2\ \ 11\ UO_3.\ \ 46\ TiO_2.\ \ 10\ H_2O.$$

The figures for RO and UO_3 are not very near whole numbers, but this need cause no disappointment as the whole calculation rests on the assumption that the iron is in the ferrous condition. Although this assumption has certain analogies to support it and is given preference, it would not be entirely unreasonable to assume that part or all of the iron is in the ferric condition. The question cannot be settled experimentally in the presence of uranium in two stages of oxidation. If all of the iron is assumed to be present as ferric iron the following percentages and molecular values are obtained in place of those first given:

	Per cent.	Molecular values.
FeO	None	—
Fe_2O_3	3.2	.020
UO_2	18.4	.068
UO_3	25.1	.089

Appropriate grouping now leads to the approximate formula:

$$2\ RO.\ \ R_2O_3.\ \ 3\ RO_2.\ \ 3\ UO_3.\ \ 18\ TiO_2.\ \ 4\ H_2O.$$

The bases are apparently present as titanates, metatitanates, or uranotitanates, but an exact evaluation of the relative pro-

portions of these compounds is obviously very difficult and hardly appears practicable in view of the uncertainty concerning the stage of oxidation of the iron and uranium. There is more TiO_2 present than is required to form normal titanates of all the bases, but not enough to form metatitanates without taking some uranium as the basic radicals UO and UO_2. To secure an exact balance any excess of TiO_2 may be reduced to the form of a titanyl metatitanate $TiO.TiO_3$.

The results below are presented for illustration as one of the possibilities along this line with little to recommend it over others that could be given.

Oxide	Molecular value	Metatitanate	TiO_2 required
RO	.096	$R\ TiO_3$	.096
Yt_2O_3	.011	$Yt_2(TiO_3)_3$	.033
ThO_2	.016	$Th(TiO_3)_2$	.032
ZrO_2	.001	$Zr(TiO_3)_2$	.002
UO_2	.038	$UO\ TiO_3$	.038
UO_3	.116	$UO(TiO_3)_2$	.232
TiO_2	.070	$TiO\ TiO_3$	.070
			.503

On this basis the mineral may be represented as a hydrated metatitanate of various bases, thus: $(Ca, Fe, UO, TiO)TiO_3 + (Th, Zr, UO)\ (TiO_3)_2 + Yt_2(TiO_3)_3 + H_2O$. Without implying exact molecular ratios the proportions of these four species would be about 6, 8, 1, 3, respectively. It should be remembered, however, that the stage of oxidation of the iron is unknown and this ignorance introduces uncertainty in these proportions. Nor is it known whether minerals of this kind should be considered as mixed crystals, solid solutions, or salts of complex acids, although in one of these suppositions may lie the correct explanation of their composition.

Analyses of the known complex uranium minerals have been arranged in the tables following so that the uranium content increases progressively toward the end of the series. The newly described mineral from Idaho is designated as *brannerite*.

It will be seen that the new mineral contains more uranium than any other except the pitchblendes. Unlike most of the others it contains no tantalum or columbium and is very high in titanium.

Comparative Analyses of the Complex Uranium Minerals.

(Arranged in the order of their uranium content.)

Name	Risōrite	Yttrialite	Zirkelite	Microlite	Yttrotantalite	Yttrocrasite	Priorite	Naēgite	Sipylite
Page, Dana's System	App. 3, p. 68	512	App. 1, p. 75	728	739	App. 2, p. 112	App. 2, p. 17	App. 2, p. 73	731
Analyst	O. Hauser	J. B. Mackintosh	G. T. Prior	Dunnington	Rammelsberg	C. H. Warren	G. T. Prior	Haga	W. G. Brown
Crys. Form[a]		A	I	I	O	O	O	T	T
Isot. or bif.[b]	Isot.	Isot.	Isot.	Isot.	Isot.	Isot to bif.	.....	Isot.	Isot.
Indices	2.05	1.758	2.19	1.930	2.15	2.13	.....	1.818	2.06
Sp. G.	.....	4.575	4.741	5.656	5.425	4.8043	.....	4.09	4.89
Ta_2O_5	4.00	.....	.....	68.43	46.25	Trace	.....	7.69	.....
Cb_2O_5	36.21	.....	.....	7.74	12.32	Present	36.68		48.66[j]
TiO_2	6.00	.....	14.95	.....	.....	49.72	21.89	.....	.....
UO_2	Undet.	.....	1.40	.....	1.61	1.98	0.49	.....	3.47[k]
UO_3	.....	0.83	.....	1.59	.....	0.64	2.14	3.03	.....
Ce_2O_3	2.88[c]	1.86	2.52	0.17[h]	2.22	2.92	4.32	.....	1.37
$(Di, La)_2O_3$	.....	2.94[e]	.....	.....	.....	.....		.....	7.98
Y_2O_3	36.28	46.50[f]	0.21?	0.23	10.52	25.67	17.11	9.12	27.94[l]
Er_2O_3		.....	.....	.....	6.71			.....	
ThO_2	Undet.	12.00	7.31	.....	.....	8.75	0.61	5.01	.....
ZrO_2	.....	.....	52.89	.....	.....	.....	.....	55.30	2.09
CaO	1.93	0.60	10.79	11.80	5.73	1.83	4.12	.....	2.61
MgO	.....	.....	0.22	1.01	.....	Trace	0.22	.....	0.05
WO_3	.....	.....	.....	0.30	2.36	1.87	.....	.....	0.16
SnO_2	Undet.	.....	.....	1.05	1.12	.....	0.29	.....	0.08
FeO	2.61	2.89	7.72	.....	3.80	.....	5.63	.....	2.04
Fe_2O_3	1.20	.....	.....	0.29	.....	1.44	.....	.....	.....
MnO	.....	0.77	.....	.....	.....	0.13	0.19	.....	Trace
PbO	Undet.	0.85	.....	.....	.....	0.48	.....	.....	.....
H_2O-	7.11	0.79[g]	1.02[g]	1.17	6.31	4.36	3.69	.....	3.19
H_2O+	.....	.....	.....	.....	.....	0.10	.....	.....	.....
X	0.90[d]	.....	.....	.....	.....	0.68[i]	.....	.....	Trace[m]
Al_2O_3	0.81	0.55	.....	0.13	.....	.....	.....	.....	.....
SiO_2	.....	29.17	.....	.....	.....	Trace	2.12	20.58	.....
Na_2O	.....	.....	.....	2.86	.....	.....	.....	.....	0.16
K_2O	.....	.....	.....	0.29	.....	.....	.....	.....	0.06
F	.....	.....	.....	2.85	.....	.....	.....	.....	[a]Trace
BeO	.....	.....	.....	0.34	.....	.....	.....	.....	0.62
	99.93	99.75	99.03	100.25	98.95	100.57	99.50	100.73	100.48

[a] A, amorphous; I, isometric; O, orthorhombic; T, tetragonal.

[b] Isotropic or birefringent. Most of the determinations of optical properties are by E. S. Larsen and were not made on type material.

[c] $(Ce, La, Nd)_2O_3$

[d] N_2, He

[e] At. wt. 162.

[f] Y earths
A. 22.67 per cent. at. wt. 110.3
B. 5.30 per cent., at. wt. 110.53
C. 4.50 per cent., at. wt. 114.9
D. 14.03 per cent., at. wt. 120.

[g] Ignition

[h] $(Ce, Di)_2O_3$

[i] CO_2

[j] Ta_2O_5 abt. 2 per cent.

[k] UO

[l] Y_2O_3 abt. 1 per cent.

[m] Li_2O [a]

Comparative Analyses of the Complex Uranium Minerals.—Continued.

(Arranged in order of their uranium content.)

Name	Near Samarakite	Hielmite	Blomstrandine	Pyrochlore	Fergusonite	Near Samarskite	Vietinghofite	Wiikite	Delorenzite
Page, Dana's System	740	741	App. 2, p. 17	726	730	740	740	App. 3, p. 85	App. 2, p. 34
Analyst	Hillebrand	A. E. Nordenskiöld	C. W. Blomstrand	Rammelsberg	W. H. Seamon	W. F. Hillebrand	A. Damour	Holmquist	J. Sterba
Crys. Form	.....	O	O	I	T	(?)	A	O	O
Isot. or bif.	.....	uniaxial (?)	Isot.	Isot.	Isot.	.....	.....	Usually isot.	.....
Indices	.....	ω=2.30 Li ϵ=2.40 Li	2.14	1.96	2.19	.....	.....	.....	.....
Sp.G.	6.18	5.82	4.82 4.93	4.22	5.6	6.18	5.53	3.8–4.8	4.7
Ta_2O_5	27.03	62.42	1.15	.....	4.08	19.34	.....	.....	.....
Cb_2O_5	27.77		23.35	58.27	43.78	27.56	51.00	23.67	.....
TiO_2	[a]	.....	27.39	5.38	.....	.....	1.84	29.58	66.03
UO_2	4.02	4.87	5.35	5.53[e]	5.81	.....	8.85[e]	1.86	9.87[m]
UO_3	.....	.....	.....	.....	.....	6.20	.....	7.37	.....
Ce_2O_3	0.54	1.07	2.48	5.50	0.66	0.41	1.57	.....	.....
$(Di, La)_2O_3$	1.80	.....		.....	3.49	1.44		.....	.....
Y_2O_3	6.41	5.19	25.62	.....	37.21	5.64	6.57	4.06	14.63
Er_2O_3	10.71	.....		.....		9.82	.....		.....
ThO_2	3.64	.....	4.28	4.96	.....	3.19	.....	.....	.....
ZrO_2	2.29[a]	.....	1.33	.....	.....	3.10[a]	0.96	.....	.....
CaO	0.27	4.26	1.80	10.93	0.65	1.61	.....	4.86	.....
MgO	.....	0.26	0.15	.....	.....	0.11	0.83	.....	.....
WO_3	2.25	6.56	.....	.....	0.76	5.51	.....	.....	.....
SnO_2	0.95		0.18	.....		0.82	.....	.....	4.33
FeO	0.32	8.06	1.43	5.53	1.81	0.39	23.00	.....	4.25[m]
Fe_2O_3	8.77	.....	.....	.....	.....	8.90	.....	7.51	.....
MnO	0.78	3.32	0.30	.....	.....	0.77[g]	2.67	1.28[k]	.....
PbO	0.72	.....	0.84	.....	.....	1.07	.....	.....	.....
H_2O-	1.58	3.26	2.56	.....	1.62	3.94	1.80[j]	11.06	.....
X	0.29[b]	0.10[c]	0.49[d]	5.28[f]	.....	.....	.....	10.55[l]	.....
Na_2O	.....	.....	0.90	5.31	.....	0.36[h]	.....	.....	.....
K_2O	0.17	.....	0.18	.....	.....	.....	.....	.....	.....
	100.31	99.37	99.78	101.16	99.87	100.18	99.09	101.80	99.11

[a] Includes some TiO_2

[b] ZnO 0.05
(Li, Na)$_2$O 0.24
CuO

[c] FeO and UO

[d] ZnO 0.09
SiO_2 ..... 0.40

[e] Ignition 1.53
F 3.75

[f] MnO and ZnO

[g] (K, Li, Na)$_2$O

[h] U_2O_3

[j] Ignition

[k] Mn_3O_4

[l] Precipitated by H_2S 1.06
Al_2O_3 ..... 9.74
SiO_2 ..... 8.75

[m] State of oxidation not determined.

Comparative Analyses of the Complex Uranium Minerals.—Continued.

(Arranged in the order of their uranium content.)

Name	Euxenite	Euxenite	Samarskite	Plumbobiobite	Nohlite	Altered Samarskite	Hatchettolite	Annerödite	Ampangabeite
Page, Dana's System	[a]	744	739	App. 3, p. 61	740	740	727	741	App. 3 p. 3
Analyst	.....	Rammelsberg	Koenig	Hauser and Finkh	Nordenskiöld	W. H. Seamon	O. D. Allen	C. W. Blomstrand	Pisan
Crys. Form	O	O	O	A	Massive	O	I	O	O?
Isot. or bif.	Isot.	Isot.	Isot.	.....	.....	.....	Isot.	.....	Isot.
Indices	2.24	2.24	2.10	.....	.....	.....	1.98	.....	2.13
Sp.G.	4.99	5.103	2.25 5.96 6.20	4.801 4.813	5.04	4.33	4.77 4.9	5.7[j]	3.97 4.29
Ta_2O_5	13.89	.....	.....	1.18	.....	.....	29.83	.....	8.90
Cb_2O_5	12.73	33.39	56.40[e]	46.15	50.43	47.09	34.24	48.13	34.80
TiO_2	27.70	20.03	.....	1.20	.....	.....	1.61	.....	4.90
UO_2	10.50[b]	12.12	13.48	13.72	14.43[g]	.....	.....	16.28[g]	19.40
UO_3	.....	.....	.....	.....	.....	15.15	15.50	.....	.....
Ce_2O_3	0.62[c]	3.50	3.85	.....	0.25	1.40	.....	2.56	0.60
$(Di, La)_2O_3$	.....	.....		.....	.....	4.00	.....	.....	
Y_2O_3	25.64	14.60	11.90	14.26	14.36	13.46	.....	7.10	4.00
Er_2O_3	.....	7.30		.....		.....	.....	.....	
ThO_2	1.34	.....	.....	0.06	.....	.....	.....	2.37	2.50
ZrO_2	.....	.....	.....	Trace	2.96	.....	.....	1.97	.....
CaO	0.09	1.36	.....	3.05	4.67	1.53	8.87	3.35	1.50
MgO	0.12	.....	.....	.....	.....	.....	0.15	0.15	.....
WO_3	.....	.....	.....	.....	.....	.....	0.40	0.30	.....
SnO_2	.....	.....	.....	0.15	.....	.....			0.80
FeO	0.51	3.25	8.98	5.70	8.09	7.09	2.19	3.38	.....
Fe_2O_3	2.63	.....	1.66	.....	.....	.....	.....	.....	8.60
MnO	Trace	.....	.....	.....	0.28[h]	.....	.....	0.20	.....
PbO	0.20	.....	.....	7.62	.....	.....	Trace	2.40	.....
H_2O-	3.00	2.40	0.30	6.38	4.62	9.55	4.49	8.19	12.40
X	0.74[d]	.....	.....	0.52[f]	0.11[i]	.....	.....	2.51[k]	.....
Al_2O_3	.....	.....	2.00	0.28	.....	.....	.....	0.28	2.10
Na_2O	.....	0.82	.....	.....	.....	.....	1.37	0.32	.....
K_2O	.....	.....	.....	.....	.....	.....	Trace	0.16	.....
	99.71	98.77	98.57	100.27	100.20	99.67	98.55	99.51	100.50

[a] Miller, Willet G., and Knight, Cyril W., Occurrence of euxenite in South Sherbrooke township, Ontario: *Am. Jour. Sci.*, vol. xliv, pp. 243–244, 1917. Name of analyst not given. Analysis made at Imperial Institute, London, England.

[b] U_3O_8

[c] $(Ce, La)_2O_3$ etc.

[d] SiO_2

[e] Sp.G., 5.77

[f] N_2, He 0.22
CO_2 ..... 0.19
MnO 0.11
CuO ..... Trace

[g] UO

[h] MnO, MgO

[i] CuO

[j] Anhydrous mineral

[k] SiO_2
Ignition

Comparative Analyses of the Compex Uranium Minerals.—Concluded.

(Arranged in the order of their uranium content.)

Name	Polycrase	Samirésite	Mackintoshite	Blomstrandite	Pilbarite[i]	Betafite	Brannerite	Pitchblende	Uraninite
Page, Dana's System	745	App. 3, p. 69	App. 1, p. 44	746	.....	.....	.....	891	891
Analyst	Mackintosh	Pisani	Hillebrand	Lindström	Simpson	Pisani	Wells	Hillebrand	Hillebrand
Crys. Form	O	I	T	Massive	A	I	.....	I	I
Isot. or bif.	Isot.	Isot.	Isot.	Isot.	Isot.	Isot.	Isot.	Opaque	Opaque
Indices	1.70	1.94	1.77	2.14	1.74	1.92	2.30	.....	.....
Sp.G.	4.97–5.04	5.24	5.438	4.17 4.25	4.68	4.475	5.42	8.07	9.59
Ta_2O_5	.....	3.70	.....	49.76	0.47	Trace	.....	.....	.....
Cb_2O_5	19.37	45.80	.....		.....	32.10	.....	.....	.....
TiO_2	28.51	6.70	.....	10.71	.....	17.30	39.0	.....	.....
UO_2	.....	21.20	22.40	23.68[g]	.....	.....	10.3	58.51	57.43
UO_3	19.47	.....	.....	.....	27.09	28.60	33.5	25.26	26.48
Ce_2O_3	.....	0.20	45.30[d]	.....	0.19	1.20	.....	0.22	0.25
$(Di, La)_2O_3$	.....		.....	.....	.....		.....	.....	0.13
Y_2O_3	21.23[a]	.....	1.86[e]	.....	0.49	.....	3.9[k]	.....	0.20
ThO_2	.....	.....	.....	.....	31.34	1.25	4.1	.....	9.79
ZrO_2	.....	.....	0.88?	.....	.....	.....	0.2	7.59	.....
CaO	0.68	.....	0.59	3.45	0.57	11.61	2.9	0.84	0.08
MgO	.....	.....	0.10	0.16	0.21	.....	.....	.....	.....
SnO_2	.....	0.10	.....	.....	.....	.....	.....	.....	.....
FeO	2.47	1.06	1.15	3.33	.....	.....	2.9	0.32	.....
Fe_2O_3	0.18	.....	.....	.....	0.20	1.38	Trace	.....	0.40
MnO	.....	.....	.....	0.04	Trace	0.25	.....	0.16	.....
PbO	0.46	7.35	3.74	.....	17.26	.....	0.2	0.70	3.26
H_2O-	4.46	12.45[c]	0.50	7.96	3.50	5.20	2.0	1.96	0.61
H_2O+	.....	.....	4.31	.....	4.16	.....	.....	.....	.....
He	.....	.....	.....	.....	Trace	.....	.....	0.15[m]	Undet.
X	0.12[b]	.....	0.67[f]	0.12[h]	1.08[l]	.....	0.6[j]	1.45[n]	0.70[b]
Al_2O_3	.....	0.74	.....	0.11	0.15	0.50	Trace	.....	.....
SiO_2	1.01	.....	13.90	.....	12.72	.....	0.6	2.79	0.16
Li_2O	.....	.....	0.68	.....	.....	.....	.....	.....	.....
Na_2O	.....	.....	.....	.....	0.04	.....	.....	.....	.....
K_2O	.....	0.30	0.42	.....	0.09	.....	.....	.....	.....
	97.96	99.60	96.50	99.32	99.56	99.39	100.2	99.95	99.49

[a] At. wt. 114.1
[b] Insol.
[c] Ignition
[d] ThO_2, Ce_2O_3
[e] La_2O_3, Y_2O_3
[f] P_2O_5
[g] UO
[h] Precipitated by H_2S
[i] Simpson, Edward S., Pilbarite, a new mineral from the Pilbara Goldfield: *Jour. Nat. Hist. and Sci. Soc. of Western Australia*, vol. iii, p. 131, 1911.
Lacroix, A., "Minéralogie de la France et de ses Colonies," vol. v, pp. 93–94, 1913.
[k] Mol. wt. 350
[l] BaO 0.3
SrO 0.1
CO_2 ..... 0.2
P_2O_5 ..... Trace
[m] Det. as N
[n] ZnO 0.44
P_2O_5 ..... 0.22
As_2O_5 ..... 0.43
$CuFeS_2$ 0.12
PeS 0.24

The only other minerals having the same general qualitative composition are zirkelite and delorenzite, and to make comparison easier their analyses are repeated.

Analyses of Zirkelite, Delorenzite, and Brannerite.

	Zirkelite Isometric	Delorenzite Orthorhombic	Brannerite Undetermined
Specific gravity	4.741	4.7	5.42
TiO_2	14.95	66.03	39.0
UO_2	1.40	9.87[a]	10.3
UO_3	.....	.....	33.5
Ce_2O_3	2.52	.....	.....
Y_2O_3	0.21	14.63	3.9
ThO_2	7.31	.....	4.1
ZrO_2	52.89	.....	0.2
CaO	.....	.....	2.9
MgO	0.22	.....	.....
SnO_2	.....	4.33	.....
FeO	7.72	4.25[a]	2.9
PbO	.....	.....	0.2
$H_2O \pm$	1.02 (ign.)	.....	2.0
Na_2O	10.79	.....	.....
SiO_2	.....	.....	0.6
BaO	.....	.....	0.3
SrO	.....	.....	0.1
CO_2	.....	.....	0.2
Fe_2O_3	.....	.....	Traces
Al_2O_3	.....	.....	
P_2O_5	.....	.....	

[a] State of oxidation not determined.

The uranium in zirkelite is almost negligible and the quantity of zirconium present puts it in a class by itself. The analysis of delorenzite makes the mineral appear almost suspiciously simple in composition, only five metals being determined, but the relationship to brannerite is closer than that of zirkelite. However, the quantity of uranium oxide is less than one-sixth that of the titanium oxide, but in brannerite the weight of uranium oxides is greater than that of titanium oxide and is more than four times as great as that in delorenzite.

The new mineral seems worthy of an individual name, and we therefore propose to call it brannerite after Dr. J. C. Branner, formerly head of the Department of Geology and Mining and President of Stanford University.

Brannerite may be described as a complex titanate of uranium with smaller quantities of rare earth and other metals, in which the weight of uranium oxides exceeds that of titanium oxide.

Industrial Employment of Very High Pressures. GEORGES CLAUDE. (*Comptes Rendus,* October 13, 1919.)—At present 200 atmospheres is about the maximum pressure used, and this chiefly in the Haber process and in the liquefaction of air. The author maintains that pressures of 1000 atmospheres can be more easily employed than those of lower amounts. Leather collars work all the better at higher pressures. It is not difficult to provide walls sufficiently strong to withstand high pressures, but it is difficult to secure tight joints. Owing to the smaller volume of containers at high pressure for the same mass of gas it is easier to make the joints tight for high pressures. As the cost of compression rises in proportion to the logarithm of the pressure the expense of compressing to 1000 atmospheres is one and a half times as much as of attaining 100 atmospheres.

G. F. S.

Some Characteristics of the Spark Discharge and Its Effect in Igniting Explosive Mixtures. C. C. PATERSON and NORMAN CAMPBELL. (*Proceedings Physical Society of London,* vol. xxxi, Pt. iv, 1919.)—For the ignition of mixtures of petrol and air a quantity of energy as small as .0004 joule was found to suffice. When the spark potential is lowered the quantity of energy requisite increases with great rapidity. A train of similar sparks has no greater igniting power than a single spark.

In the ignition of hydrogen and air it was found that reduction of the radius of curvature of the electrodes augmented the igniting power.

Experiments on an aeroplane engine showed that satisfactory ignition could be obtained by the use of quantities of energy much smaller than those supplied by a magneto or by a battery and coil system.

G. F. S.

The Speed of Sound Pulses in Pipes. A. L. FOLEY. (*Physical Review,* August, 1919.)—A sound pulse of cylindrical form was produced by an electric spark. It spread out from the line source, in part travelling in the open air and in part passing through various tubes set with their axes perpendicular to the line of the spark. This pulse was illuminated for an instant by a second spark and its shadow, due to its having a density different from that of the surrounding air, was caught and recorded on a photographic plate. The distance each portion of the pulse had come could thus be observed. It was found that the speed is greater or less in short tubes than in the free air, according to position with respect to the source, but that in longer tubes the speed, at first greater than in free air, gradually lessens and finally becomes smaller. The intensity of the pulse when it enters the pipe seems to be that which determines the speed. The greater the intensity the greater the speed.

G. F. S.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

DISTRIBUTION OF ENERGY IN THE SPECTRUM OF AN ACETYLENE FLAME.[1]

By W. W. Coblentz.

[ABSTRACT.]

THIS paper gives new data on the distribution of energy in the infra-red spectrum of a flat and of a cylindrical acetylene flame.

This paper gives also a revision of previously published spectral energy data, pertaining to the violet end of the visible spectrum. This revision has no effect upon the previously published visibility, in the region of the spectrum in which the attempt has been made to attain high accuracy in the visibility data.

MAGNETIC TESTING OF STRAIGHT RODS IN INTENSE FIELDS.[2]

By W. L. Cheney.

[ABSTRACT.]

FORMER experiments, as performed by Ewing and Low, Pierce, Hadfield and Hopkinson, du Bois and Jones, Gumlich, Campbell and Dye, *et altera.*, to determine the intensity of magnetization with high magnetizing forces, involved the use of very small specimens. Frequently, it is desirable to make such tests with fairly long rods and since the usual types of permeaters do not permit the use of very high magnetizing forces, a method whereby magnetic tests can be made upon these rods in intense fields has been developed.

The apparatus consists essentially of a du Bois electro-magnet with flat pole pieces separated by an air gap and pierced coaxially so that a rod may be extended through them and the electro-magnet. Surrounding the specimen are three coaxial test coils wound on brass forms. When the inner coil is connected in series with

* Communicated by the Director.

[1] Scientific Paper No. 362.

[2] Scientific Paper No. 361.

a balistic galvanometer, the normal induction is measured by the throw of the galvanometer upon reversal of the magnetizing current. By connecting either the inner and middle or middle and outer coils in opposition the value of the magnetizing force is determined.

Normal induction curves obtained for a number of specimens of different materials show very good agreement with similar curves obtained by the Burrows method within the range of the latter. Hysteresis values, however, have not proved so reliable and are being studied further with the hope of satisfactory improvement.

From the normal induction data, the intensity of magnetization and reluctivity are calculated and discussed from the point of view of revealing in some specimens the presence of two constituents of different degrees of hardness which reach the maximum intensity of the magnetization for different values of H.

NOTE ON METHODS OF COMPUTING AND INTERCOMPARING RADIATION DATA.[3]

By W. W. Coblentz.

[ABSTRACT.]

A SIMPLE method is given for computing spectral energy curves using the Planck formula. A table of values of log $(e^u - 1)$ is given for this purpose. By means of this table, a table of logarithms and a slide rule, a complete spectral energy curve can be computed in an hour.

The paper gives also a chart for the intercomparison of thermal radiation constants with similar data, obtained indirectly from ionization potential, photo-electric and X-ray measurements.

CONCERNING THE ANNEALING AND CHARACTERISTICS OF GLASS.[4]

By A. Q. Tool and J. Valesak.

[ABSTRACT.]

THE characteristics involved in annealing were investigated for a number of glasses of different composition. The glasses

[3] Scientific Paper No. 360.

[4] Scientific Paper No. 358.

studied were chiefly those produced by the Bureau of Standards at Pittsburgh. Any common process of annealing may be considered as made up of three factors, namely: the annealing temperature, the time allowed for the reduction of the stresses, and the rate and mode of cooling.

One method which appears very dependable for determining the practical range of annealing temperatures consists of locating the temperature interval in which the glass on being heated shows a distinct and fairly sharp increase in the heat absorption. All glasses investigated showed this effect. It always occurred in a temperature range in which the glass was soft enough to allow a practically complete relaxation of the stresses in an unannealed sample in a very short period. The rapidly increasing softness of the glass at these temperatures and the increase in the heat absorption are undoubtedly related, but the nature of the relationship is as yet undetermined.

The rate of the relaxation of the stresses in the glass was determined at different temperatures by the use of two methods; first, by measuring the rate of deformation of loaded strips on rods; and, second, by determining the rate at which the double refraction in unannealed glass disappeared. The data thus obtained, as previous investigations also show, aid greatly in determining the practical annealing temperature, the time the glass should be held at this temperature, and a satisfactory cooling procedure.

THE CONSTANTS OF RADIATION OF A UNIFORMLY HEATED ENCLOSURE.[5]

By W. W. Coblentz.

[ABSTRACT.]

EXPERIMENTAL data are given on atmospheric absorption. The paper gives also a recalculation of the coefficient of total radiation of a uniformly heated enclosure, or so-called black body, giving a value of

$$\sigma = 5.72 \times 10^{-12} \text{ watt cm}^2 \text{ deg}^{-4}$$

The effect of atmospheric absorption is discussed, and the

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[5] Scientific Paper No. 357.

conclusion arrived at is that, if corrections are made for atmospheric absorption, the value recently obtained at Naples is close to the average value, viz.,

$$o = 5.7$$

In the second part of the paper, the present status of the constant of spectral radiation is discussed.

THE ULTRA-VIOLET AND VISIBLE TRANSMISSION OF VARIOUS COLORED GLASSES.[6]

By K. S. Gibson, E. P. T. Tyndall, and H. J. McNicholas.

[ABSTRACT.]

DURING the last three years the spectral transmissions of a great number and variety of glasses have been measured by the Bureau of Standards throughout the ultra-violet, visible, and infra-red. The transmissions throughout the infra-red, and extending into the visible, have already been published,* as well as the transmissions for the visible and ultra-violet of glasses particularly classed as eye-protective.† In the present paper are given the transmissions for the visible and ultra-violet of 87 samples of glass, representing over 50 different kinds, mostly colored, which are not used primarily for eye-protection, but which are useful for various other special purposes. The glasses listed in this and the other papers mentioned, are representative of what may be obtained to-day on the American market, and include also some of foreign make which were obtainable before the war. It is thus possible to compare the relative merits of foreign and American glass, and see in what respect the latter may duplicate or improve upon the former.

All of the glasses of this paper, so far as it was possible to get values, were measured photographically and visually, and in most cases photoelectrically. The photographic (Hilger sector photometer with quartz spectograph) method may be used from

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[6] Technologic Paper No. 148.

* Coblentz and Emerson: B. S. Tech. Paper No. 93, May, 1917; 3rd edition, February, 1919. Coblentz, Emerson, and Long: B. S. Sci. Paper No. 325, August, 1918.

† Gibson and McNicholas: B. S. Tech. Paper No. 119, June, 1919.

230 to 500 millimicrons, the photoelectric (null method) from 380 to 600, and the visual (Koenig-Martens spectrophotometer) from 436 to 720. The data are presented in the form of transmission curves extending from 720 millicrons throughout the visible and ultra-violet as far as the specimens have any appreciable transmission. The methods overlap to such an extent that when all are used extremely reliable curves may be obtained. With possibly a few exceptions, therefore, the curves as given in this paper are considered accurate within 0.02 on the transmission scale of 0.00 to 1.00, and in many cases, especially at low transmissions and in the better specimens, the uncertainty is less than this.

For each specimen are given the transmission curve, the thickness, the trade name or designation, and the maker or dealer. In each figure also is given the relative visibility curve for the average human eye. An inspection of the curves must be made by those interested, inasmuch as this kind of data cannot be summarized.

Various practical uses to which these glasses are put are indicated, such as ultra-violet signaling, railway signaling, improvement of visibility both for visual and photographic work, protection of the eyes, and selective ray filters. Of special value in scientific work is their use as filters to obtain monochromatic light from the mercury, helium, or hydrogen lamps. Transmission curves of such filters are given.

NOTES ON THE MICROSTRUCTURE OF IRON AND MILD STEEL AT HIGH TEMPERATURE.[7]

By Henry S. Rawdon and Howard Scott.

[ABSTRACT.]

THE microstructure of iron and mild steel which prevails at high temperatures was studied by means of "heat-etching." The polished specimens were heated in vacuo to the desired temperature; volatilization of the metal from the surface is sufficient, together with the volume changes in the critical transformation, to produce an etched pattern on the previously polished face which

[7] Scientific Paper No. 356.

records the type of structure existing at that temperature. No change occurs in the type of microstructure upon heating until the temperature of the A_3 transformation is reached. Above this temperature the structure is radically different from that which prevails below.

The composition of the metal at the surface of the heated specimen changes considerably during the heating. The extent and nature of the change was determined; it is essentially a decarburization. Such decarburization does not occur until all the carbon is in the form of a solid solution, *i.e.*, until the temperature of the A_1 transformation is passed. The effect of this composition change upon the indications of the etching pattern by which the structure is revealed is discussed. This method of heat-etching is sensitive enough to reveal the true structure of the metal in spite of the change which occurs later in the composition of the surface metal.

THE EFFLUX OF GASES THROUGH SMALL ORIFICES.[8]

By Edgar Buckingham and Junius David Edwards.

[ABSTRACT.]

THIS paper contains a theoretical discussion of the results of experiments made during an investigation of the effusion method of determining gas density; and it is a sequel to the paper in which that investigation has already been described by one of the present authors.* The effect on effusion of viscosity and thermal conductivity of the gas are studied, and formulas for representing these effects are developed and compared with the observed facts. A physical interpretation is thus obtained for the most striking of the apparent anomalies observed in the behavior of gases flowing through very small orifices such as are used in apparatus for determining density by effusion. The mathematical work was, unavoidably, too cumbersome for satisfactory abstraction. The resulting agreement of the theory with the observations is exhibited graphically. It is fairly satisfactory but not perfect, and its imperfections suggest the directions in which further experiments should be made.

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[8] Scientific Paper No. 359.

* Edwards: Techn. Paper Bur. Standards, No. 94, June 20, 1917.

RECOMMENDED SPECIFICATION FOR BASIC SULPHATE WHITE LEAD.[9]

[ABSTRACT.]

PREPARED and recommended by the U. S. Interdepartmental Committee on Paint Specification Standardization, September 22, 1919. This committee was appointed at the suggestion of the Secretary of Commerce, and consisted of representatives of the War, Navy, Agriculture, Interior, Post Office, Treasury, and Commerce Departments, the Railroad Administration, the Panama Canal, and the Educational Bureau of the Paint Manufacturers' Association of the United States. The committee submitted a preliminary draft of this specification to a number of representatives of the paint and varnish industry, including all of the large manufacturers of white lead, and gave careful consideration to the replies received in time.

This specification gives chemical and physical requirements for dry basic sulphate white lead and basic sulphate white lead ground to a paste in linseed oil. Methods of sampling and methods of testing both dry pigment and the paste are made part of the specification. For details, the original should be consulted.

Benzol Poisoning.—According to R. P. ALBAUGH (*Modern Medicine,* 1919, i, 670), benzol or benzene is one of the most important industrial poisons. Poisoning due to benzene may occur in the manufacture of aromatic hydrocarbons, or in the technical use of products containing these hydrocarbons, *e.g.,* in the removal of grease from goods, and in the manufacture of varnish and rubber. The poisoning may be mild or severe, acute or chronic, and may have fatal results. When man is exposed to a mixture of benzene and air, he absorbs 80 per cent. of the benzene; the limit for animals is from 0.015 to 0.016 parts of benzene to 1000 parts of air. Distillations should be carried out in impervious apparatus with well-cooled condensers. All apparatus which has contained benzene should never be entered for cleaning or repairs until all benzene has been removed, and thorough ventilation has occurred. The workmen should have approved breathing apparatus. A person overcome by benzene should be removed into fresh air promptly, and given artificial respiration. Women are more susceptible than men to benzene poisoning.

J. S. H.

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[9] Circular No. 85.

Platinum in 1919. (*U. S. Geological Survey Press Bulletin,* No. 435, December, 1919.)—The platinum market during the first quarter of 1919 was easier than in 1918, owing to the facts that the governmental restriction on the use of platinum had been removed and that the Government was disposing of its surplus stocks. The low price of $99 an ounce was reached late in March and was maintained about a month, but the price gradually stiffened until August, when the Government stocks were exhausted, and then abruptly rose to $110 an ounce. Since the middle of August the price has continued to advance about $5 an ounce a month, the demand for the metal has been strong, and the supply has been short.

During the first nine months of 1919 about 40,400 ounces of platinum were imported, and importation at this rate will probably be continued during the rest of the year, so that if the normal domestic production of 7000 to 10,000 ounces is maintained, about 54,800 ounces of new platinum should be available, aside from the stocks of platinum, about 65,000 ounces, held at the beginning of 1919.

So far as known there has been little change in the domestic mining of platinum. The wide search made in 1918 for domestic sources of platinum has apparently yielded little results. Colombia may supply more crude platinum in 1920 than in the past, but its producing capacity is limited by the methods employed in washing the gravels from which the metal is obtained. Practically no supplies can be expected from Russia for several years. The osmiridium field of Tasmania appears to need only higher prices to stimulate larger production, but even with this stimulus it can probably produce not much more than 2000 ounces a year.

According to James M. Hill, of the United States Geological Survey, Department of the Interior, there seems to be little hope of any marked increase in the output of platinum in the United States or Canada over the small output heretofore made, and as the supplies are below normal and the demand is large it is reasonably certain that the price of platinum metals in this country during 1920 will be at least as high as it was during the last quarter of 1919, and possibly higher.

Energy Requirements of Man.—*The Weekly News Letter, U. S. Department of Agriculture,* December 31, 1919 (vol. vii, No. 22, page 3–4), states that a family consisting of father, mother, and three children requires approximately 12,000 calories per day. These may be divided into 120 portions of 100 calories each. The diet is best balanced by dividing these 120 portions among certain groups of foodstuffs: Fruits and vegetables, 24; milk, eggs, and meats, 36; cereals and legumes, 30; sugar and sugary foods, 12; fats and fatty foods, 18.

J. S. H.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

INTENSIFICATION AND REDUCTION WITH PYRO DEVELOPERS.[1]

By R. B. Wilsey.

It is well known that a pyro developed negative has a greater printing density and contrast than a neutral negative of equal visual density and contrast. The strength of the pyro color can be varied over a wide range by suitably altering the concentrations of the constitutents of the developer, especially that of the sulphite. These facts suggested the possibility of using the pyro color as a means of photographic intensification, or its removal to produce photographic reduction. A pyro negative may be bleached in a ferricyanide bleach without losing its color, and redeveloped in a pyro developer to produce another deposit of stain and thus intensification, or it may be bleached in a permanganate bleach, removing the color, and redeveloped in a formula giving it a lower photographic contrast. A neutral negative may be bleached in either ferricyanide or permanganate bleach, and intensified by redeveloping in a pyro developer.

These various possibilities were investigated with sensitometer strips made upon Seed 30 plates. Printing contrasts were determined from prints upon positive motion picture film. It was found that a negative of normal pyro color (developed in pyro 5–10–10) could be reduced to about half its original photographic contrast by bleaching in permanganate bleach and redeveloping in elon-hydroquinone. By bleaching in ferricyanide bleach, and redeveloping in pyro without sulphite (pyro 5–10–0), the printing contrast was nearly doubled. The printing contrast of an elon-hydroquinone negative was doubled by bleaching in permanganate bleach and redeveloping in pyro 5–10–0. Lesser degree of reduc-

* Communicated by the Director.

[1] Communication No. 83 from the Research Laboratory of the Eastman Kodak Company, published in *Phot. J. Amer.*, 1919, p. 558, and *Brit. J. Phot.*, 1919, p. 721.

tion or intensification was obtained by redeveloping in pyro developer having a suitable concentration of sulphide.

The process of intensification was repeated five times upon a single negative, which gave it a printing contrast nearly three times that of the original negative. The advantages of this method are that, within certain limits, any degree of intensification or reduction can be produced by suitable variations in the sulphite concentration of the redeveloper; the reduction or intensification is proportional, the contrast being changed by the same ratio for all parts of the negative. The degree of reduction or intensification that can be obtained compares favorably with that of other methods.

Desiccated Vegetables.—PHILIP B. HAWK of Jefferson Medical College (*Science*, 1919, xlix, 329–330) comments on the behavior of desiccated vegetables. When they are immersed in water for a few hours they assume a form closely approaching that of the fresh vegetable. If the swollen mass be removed from the water and permitted to remain at room temperature for twenty-four to thirty-six hours, it returns to the anhydrous state, and therefore behaves in an entirely different manner from a fresh article. Hence a fresh vegetable and a swollen desiccated vegetable are entirely different structurally. The failure of the swollen desiccated product to retain its water as well as the fresh article may be due to a change in the colloids of the vegetable cells with an accompanying decrease in their power to hold water, or may be due to removal of salts during the soaking and a resulting decrease in inhibition power of the colloids.

J. S. H.

Utilization of the Rhone in French Territory.—In August, 1919, the Senate and the Chamber of Deputies adopted articles providing for this great engineering work. The estimated cost is 2,500,000,000 francs and fifteen years will be spent on the project. From Lake Geneva to the Mediterranean there is a fall of 372 metres. It is estimated that 1,800,000 horsepower can be developed. "The Rhone represents a mine as rich as all the coal fields of the north of France," a fortunate circumstance for France in view of the systematic destruction of her coal mines by the Germans.

In addition to the development of power the navigation of the river will be improved. At present there is almost no use made of the stream from Geneva to Lyons as a waterway. Water for irrigation will be provided for the departments of Gard, Bouches-du-Rhone and elsewhere.

G. F. S.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

VANILLYL ACYL AMIDES.[1]

By E. K. Nelson.

[ABSTRACT.]

THE author's investigation of capsaicin,[2] which demonstrated that substance to be a vanillyl decenoyl amide, has led to the synthesis of a number of other vanillyl acyl amides (4-hydroxy-3-methoxy benzyl acyl amides), of the type $(4)HO(3)CH_3O.C_6H_3(1)CH_2NHCOR$.

The condensation products of vanillyl amine with acetic, propionic, butyric, isobutyric, *n*-hexoic, *n*-heptoic, *n*-octoic, *n*-nonoic, *n*-decoic, *n*-undecoic, *n*-dodecoic, crotonic, undecenoic and benzoic acids have been prepared and described. Optical-crystallographic data are given. The products from valeric, isovaleric, cinnamic and two decenoic acids failed to crystallize.

In the homologous series of derivatives of saturated fatty acids, the solubility in water decreases, while the solubility in ether increases, with rising molecular weight. Pungency to the taste, absent in vanillyl acetamide, increases to a maximum in vanillyl *n*-nonoylamide, which is about as pungent as capsaicin, one eight-thousandth milligram of either substance causing a distinct burning on the tip of the tongue. Pungency in the derivatives of still higher molecular weight decreases or changes in character, becoming less quickly evident and affecting the back of the tongue and throat.

These relations run parallel with the observations of Backman[3] and Durrans[4] on odorous substances, which showed, respectively, that a substance, to be odorous, must be somewhat soluble in both water and lipoids, and that, in homologous series, the maximum odor is found in substances of intermediate molecular weight.

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* Communicated by the Chief of the Bureau.

[1] Published in *J. Am. Chem. Soc.*, vol. xli, Dec., 1919, pp. 2121–30.

[2] Nelson: *J. Am. Chem. Soc.*, vol. xli, 1919, p. 1115.

[3] Backman: *J. physiol. path. gen.*, vol. xvii, 1917, p. 1.

[4] Durrans: *Perfumery and Essential Oil Record*, vol. x, 1919, p. 104.

LABORATORY EXPERIMENTS ON THE MANUFACTURE OF CHINESE ANG-KHAK IN THE UNITED STATES.[5]

By M. B. Church.

[ABSTRACT.]

ANG-KHAK or red rice, a common Chinese vegetable color, is used in food products of China. Its character is due to the growth of certain strains of a mold, *Monascus purpureus* Went, throughout specially treated rice kernals. This mold is so utilized only in the Orient. Certain strains of the same fungus have been found in America in corn silage and on "freckled" salt codfish. The finished red rice is composed of clear-cut grains of a dark red color, and crumbles easily into a fine, soft, red power. On contact with watery solutions, it breaks down into similar fine particles. In the manufacture of red rice the water content of the uninoculated rice must be suitably adjusted. Temperature also must be considered. In these laboratory experiments a 25 per cent. water content at room temperature (22-24° C.) was successful. Other water contents caused the mold-infected rice grains to split into flinty fragments rather than to break down into a powder. As the physiological activity of each strain of *Monascus purpureus* may vary quantitatively, it is necessary to resort to the selection of strains in order to produce successful red rice.

Flax Growing Within the Empire. (*Journal of Royal Society of Arts,* November 7, 1919.)—Before the war Britain needed about 100,000 tons of this fibre. Seventy to 80 per cent. came from Russia, while Belgium, France and Holland contributed a total of 10 per cent., and Ireland as much. The over-running of the flax-growing parts of France and Belgium was followed by the collapse of Russia. This was met by an extension of the acreage under flax in Scotland and England, but especially in Ireland, where in 1914 there were 49,000 acres and in 1918 143,000, chiefly in Ulster.

The present outlook for an adequate supply of flax is not satisfactory. It is not yet determined whether it is possible to establish the industry permanently in Great Britain under modern conditions of wages and machinery. G. F. S.

Revue Générale de l'Electricité, November 15, 1919, contains an illustrated article by GEORGE P. ROUX on "The Energy Distributing System of the Philadelphia Electric Company." Special emphasis is laid upon the "load dispatcher" and the apparatus employed by him. G. F. S.

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[5] Published in *J. Ind. Eng. Chem.*, vol. xii, No. 1, Jan., 1920, p. 45.

NOTES FROM THE U. S. BUREAU OF MINES.*

EXPERIMENT STATION OF THE BUREAU OF MINES.

By Van H. Manning.

In the ten years that have elapsed since the Bureau of Mines was first established its centres of activity have increased in number from a single station, at Pittsburgh, to eleven stations at strategic points, the most remote being at Fairbanks, Alaska. Each station has its part in the work of the Bureau as a whole and it also has an integral function as the local centre for Federal aid to the mineral industry. In Bulletin 75 of the Bureau of Mines the equipment and the work that has been and is being done at each station is described in sufficient detail so that anyone familiar with the work of only one station can secure an adequate idea of what is being done elsewhere, and what the facilities of the Bureau as a whole are. The safety and rescue stations of the Bureau are also briefly described in this Bulletin for although these are not properly experiment stations, some investigative work on mine sanitation and hygiene is carried on at them.

USE OF BREATHING APPARATUS IN GASOLINE VAPORS.

By A. C. Fieldner, L. H. Katz, and S. P. Kinney.

The use of oxygen-breathing apparatus in gasoline vapors of high concentration is attended with considerable danger because the vapor permeates the rubberized fabric of the breathing bag. Jas. S. Cunningham, foreman miner of the Bureau, lost his life through entering a gasoline storage tank while wearing such apparatus. Tests have therefore been made of the effect of gasoline vapors on breathing apparatus, and these experiments show that the thin rubberized coating used on the Salvus half hour oxygen-breathing apparatus is rather easily penetrated by both liquid gasoline and high concentrations of gasoline vapor, such as may be expected in a tank containing some volatile casing-head gasoline. While ordinary motor gasoline does not seem

* Communicated by the Director.

to produce high enough concentrations of gas to penetrate in dangerous quantities through a bag free from defects in a period of 10 to 15 minutes, yet the need of a much more impermeable bag is certainly demonstrated.

The bags now furnished with some half hour types of breathing apparatus, such as the ones tested, consist of cloth fabric coated with a thin rubber cement-like material that is decomposed by gasoline and is penetrated by the vapors in a much greater degree than the heavier rubber fabrics used on the two hour types of apparatus. These heavier bags must also be under suspicion for such purposes until thoroughly investigated.

The Bureau of Mines is taking up this subject with a view to recommending more impermeable materials not attacked by gasoline or similar liquids. In the meantime, users of oxygen-breathing apparatus in high concentrations of gasoline, benzol and other organic vapors should observe all precautions and always attach a life line to the wearer so that he can be immediately drawn out of the dangerous atmosphere should he show distress.

WASTE AND CORRECT USE OF NATURAL GAS IN THE HOME.

By S. S. Wyer.

NATURAL gas is a community asset and every consumer has a right to demand that wasteful use be prohibited in the interest of the general service. Of all the gas sold as a public utility service in the United States, three-fourths is natural gas. The average price of natural gas to the domestic consumer is 30 cents per thousand cubic feet; the average price of manufactured gas is $1.00 per thousand cubic feet. Of the natural gas delivered to the domestic consumer 80 per cent. is wasted through the use of inefficient appliances for its burning. By relatively simple and inexpensive adjustments in such appliances it is quite possible to make one cubic foot of gas do the work now done by 3 cubic feet. This would make a gas supply available for consumers who are now unable to obtain any, and postpone the time when, through exhaustion of the natural supply, consumers will generally have to turn to the use of manufactured gas. Details as to the sources of waste in the use of natural gas in the home, and the means which should be adopted for their cor-

rection are given in a Technical Paper of the Bureau of Mines. A conference called by the Secretary of the Interior met in Washington January 15, as a result of which a committee of 10 was appointed to take suitable steps to lessen this loss.

MINOR NOTES.

Smoke Nuisance.—Salt Lake City has a serious problem in the smoke that is being generated within the city limits and the City is coöperating with the Bureau of Mines in studying the problem and ascertaining the steps to be taken for its solution. Determinations of the soot fall during October indicate that it ranged from 8.6 to 37.9 tons per square mile. As the hypothesis had been advanced that the smoke from the smelters drifted in above the city and prevented the city smoke from rising and becoming dissipated, one of the Bureau investigators made an airplane flight above the city to take samples of the air at the upper levels. These showed only a trace of SO_2, indicating that smelter smoke was not present in appreciable amounts.

Colorado Oil Shales.—A coöperative agreement has been entered into between the Bureau and the State of Colorado for the expenditure of $10,000 under the direction of the Bureau on investigations of the oil shales of Colorado. The work is to be done at the University of Colorado, where laboratory facilities have been provided. M. J. Gavin, of the Bureau, has been designated to have charge of the work.

Geophone Tests.—Recent tests made with the geophone indicate that nickel diaphragms give a greater range for intercepting sound waves than any material previously tried. In a recent test at Mullan, Idaho, the geophone successfully located a leak in a 12-inch buried water main after a great deal of money had been spent in attempting to locate the leak by ordinary means, but without result.

Coal Inspection.—The estimates for appropriations for the Bureau for 1920–1 contain an item providing for the creation of an inspection and certification service for coal much like the present inspection of meats, except that it will not be compulsory, reliance being placed on the advantages of the service to secure its general adoption. The mining companies would set their own standards for their average product. Sampling plants would be

established at strategic points and enough of the coal passing these points would be sampled to determine whether the standard of product is being maintained or not. That adequate sampling methods can be easily provided is obvious to anyone familiar with smelter sampling in the western United States. This would give the consumer a means of knowing what he is buying, and, while it is not part of the plan, it seems probable that coal of guaranteed quality would sell at a sufficient premium to cover the cost of sampling.

Tunnel Atmosphere.—The New York and New Jersey Vehicular Tunnel Commission has asked the Bureau to undertake an investigation of the atmospheric conditions likely to exist in the tunnel under conditions of normal use, especially from the standpoint of the effect of the exhaust gases from motor vehicles. A series of road tests on 80 motor vehicles, both passenger cars and trucks, is well advanced and chamber tests on human subjects in a chamber representing a section of the tunnel are about to be started. The road tests give results differing somewhat from the block tests, heretofore available, as might have been expected. Vehicular tunnels are being constructed in other cities and the results will be of general service, as well as furnishing further data on the use of internal combustion engines underground.

Atomic Orientation. T. R. MERTON. (*Phil. Mag.*, October, 1919, p. 463.)—The atoms in a crystal are arranged in a regular manner. Each atom has one or more electrons revolving about a nucleus at the centre. A line through this nucleus and perpendicular to the orbital plane is the axis of the atom. Are these atomic axes oriented in a regular manner within the crystal or are they pointed in all directions? A second question is this: If the crystal is radioactive does the direction in which the alpha and beta particles are thrown off bear some fixed relation to the atomic axis?

To seek an answer to the two questions proposed the alpha ray activity was investigated from different faces of crystals of uranium nitrate. No difference was found. Thus either or both questions appear to have a negative answer.

G. F. S.

THE FRANKLIN INSTITUTE.

(Proceedings of the Annual Meeting held Wednesday, January 21, 1920.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 21, 1920.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership since last report, 5.

Reports of progress were presented by the Committee on Library and the Committee on Science and the Arts.

The tellers of the election, Messrs. Jennings, Colvin, and Picolet, submitted the report of the ballots cast for President, Vice-Presidents, Treasurer, and members of the Board of Managers, and the following gentlemen were declared duly elected to the respective offices:

Walton Clark, President (to serve one year).

Coleman Sellers, Jr., Vice-President (to serve three years).

Charles Day, Vice-President (to serve one year).

Cyrus Borgner, Treasurer (to serve one year).

Gellert Alleman, G. H. Clamer, Theobald F. Clark, Walton Forstall, Benjamin Franklin, Harry F. Keller, George D. Rosengarten, William C. Wetherill, Managers (to serve three years).

Howard Graham, C. C. Tutwiler, Managers (to serve one year).

A vote of thanks was extended to the tellers for their services.

The President presented a statement of the work of the Institute for the fiscal year ending September 30, 1920, with the reports of the various standing committees of the Institute and Board of Managers.

The President then announced that the Aero Club of Pennsylvania was meeting jointly with the Institute, and requested Mr. Joseph A. Steinmetz, President, to preside.

Mr. Steinmetz introduced Dr. J. C. Hunsaker, Commander, Construction Corps, U. S. Navy, Navy Department, Washington, D. C., who presented the communication of the evening, entitled "U. S. Naval Aircraft." Consideration was given to the development of aircraft for the Naval Air Service as influenced by Naval requirements. An account was also given of the engineering investigations upon which the design of modern Aircraft is based. Detailed descriptions were given of the various seaplanes, balloons and airships which were used during the recent war by the Navy. Guns and gunmounts, torpedo carriers, bomb-carrying devices and other auxiliary apparatus were fully described. The subject was illustrated by numerous lantern slides.

On motion, duly seconded, a rising vote of thanks was extended to Commander Hunsaker for his interesting paper.

Adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, January 7, 1920.*)

HALL OF THE INSTITUTE,
PHILADELPHIA, January 7, 1920.

MR. BENJAMIN FRANKLIN *in the Chair.*

The following report was presented for final action:

No. 2740: Barker Wrenchless Chuck. Howard N. Potts Medal awarded to Wendell Addison Barker, of Elkhart, Indiana.

The following report was presented for first reading:

No. 2733: Hays Automatic CO_2 and Draft Recorder.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A joint meeting of the Section, the Aero Club of Pennsylvania, and the Physics Club of Philadelphia was held in the Hall of the Institute on Thursday evening, January 8, 1920, at 8 o'clock.

Dr. George A. Hoadley opened the meeting on behalf of the Institute, and introduced as the presiding officer Dr. Thomas D. Cope, President of the Physics Club, who presented the speaker of the evening, Dr. David L. Webster, Captain, Aviation Section (flying status), Signal Officers' Reserve Corps; Assistant Professor of Physics in the Massachusetts Institute of Technology. Dr. Webster delivered an illustrated lecture on "The Physics of Flight," in which the fundamental physics of flight and their application by the pilot were described.

The communication was discussed by Drs. Russell, Ives, Cope, and Webster, and Lieutenant Wetherill. On the motion of Dr. Russell, a vote of thanks was extended to Dr. Webster. The meeting then adjourned.

JOSEPH S. HEPBURN,
Secretary.

Section of Physics and Chemistry.—A joint meeting of the Section, the Philadelphia Section of the American Institute of Electrical Engineers, and the Physics Club of Philadelphia was held in the Hall of the Institute on Thursday evening, January 15, 1920, at 8 o'clock. Dr. George A. Hoadley on behalf of The Franklin Institute, Dr. C. E. Clewell on behalf of the American Institute of Electrical Engineers, and Dr. Thomas C. Cope on behalf of the Physics Club, presided jointly. The minutes of the joint meeting of January 8th were read and approved.

Dr. Clewell introduced Lee de Forest, Ph.D., Sc.D., of New York City, who delivered an illustrated lecture on "The Audion—Its Action and Some Recent Applications." The history of the Audion was traced from the original gas flame detector, through the two-electrode vacuum detector and valve, to the three-electrode relay or modern Audion. An account was given of the application of the Audion as a telephone repeater, generator of alternating

currents of both high and low frequency, autodyne and heterodyne receiver, and transmitter for radio telephone and telegraph, and of its use in the directional receiving and in "wired and wireless," and for other purposes.

After a discussion of the communication, a rising vote of thanks was extended to Dr. de Forest, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(*Stated Meeting, Board of Managers, January 14, 1920.*)

RESIDENT.

MR. FREDERIC E. BALDWIN, retired, 2200 Walnut Street, Philadelphia, Pa.

PROF. MONROE B. SNYDER, Director of Philadelphia Observatory, Central High School, Broad and Green Streets, Philadelphia, Pa.

NON-RESIDENT.

MR. WILLIAM C. BRINTON, JR., Chief Engineeer, Philips-Brinton Company, Kennett Square, Pa.

MR. EDWIN S. PHILIPS, President, Philips-Brinton Company, Kennett Square, Pa.

MR. EDWARD E. WHITE, Civil Engineer, Glen White, West Virginia.

CHANGES OF ADDRESS.

MR. WALTER ATLEE, 1709 John Street, Baltimore, Md.

MR. JOHN VAUGHAN BOSTWICK, 257 S. 16th Street, Philadelphia, Pa.

MR. CHARLES E. FOSTER, St. George Road, Ardmore, Pa.

MR. GEORGE BERKELEY REED, U. S. Submarine School, New London, Conn.

MR. THOMAS SPENCER, 3523 Balsam Avenue, Indianapolis, Ind.

MR. G. A. WELLS, 352 William Street, East Orange, N. J.

MR. ALAN WOOD, 3rd, Georgetown, S. C.

LIBRARY NOTES.

PURCHASES.

BARNETT, E. DEB.—Coal Tar Dyes and Intermediates. 1919.

CAIN, J. C.—Manufacture of Intermediate Products for Dyes. 1919.

DINGER, H. C.—Hand-Book for the Care and Operation of Naval Machinery. 1918.

JONES, H. C.—Hydrates in Aqueous Solution. 1907.

KAPP, GISBERT.—Principles of Electric Engineering, vol. ii. 1919.

MEAD, D. W.—Hydrology, the Fundamental Basis of Hydraulic Engineering. 1919.

MORLEY, ARTHUR.—The Strength of Materials. 1919.

National Association of Railroad Commissioners, Proceedings No. 30, 1918.

NUTTING, P. G.—Outlines of Applied Optics. 1912.

PRENTICE, C. F.—Ophthalmic Lenses. 1907.

Readers' Guide to Periodical Literature, Supplement No. 7. 1919.
SCHENCK, RUDOLPH.—Physical Chemistry of the Metals. 1919.
STANLEY, RUPERT.—Text-Book of Wireless Telegraphy. 2 vols. 1919.
TEED, P. L.—Chemistry and Manufacture of Hydrogen. 1919.
West Virginia—Geological Survey, County Reports and Maps. Fayette Co. 2 vols. 1919.
WHITTAKER, C. M.—Application of the Coal Tar Dyestuffs. 1919.

GIFTS.

Alberger Pump and Condenser Company, Catalogue F. New York, 1919. (From the Company.)
Alexander Brothers, Engineering Data. Philadelphia, Pa., 1919. (From Alexander Brothers.)
Allied Machinery Company of America, Catalogue of Metal Working Machinery. New York, no date. (From the Company.)
American Institute of Mining and Metallurgical Engineers, Transactions, vol. lx. New York, N. Y., 1919. (From the Institute.)
Austin, F. C., Company, Inc., Catalogue No. 7. Chicago, Ill., 1919. (From the Company.)
Bailey Meter Company, Bulletins Nos. 30 and 41. Cleveland, Ohio, 1919. (From the Company.)
Bicycle Manufacturers' Association, Catalogue of Industrial Transportation. Hartford, Conn., 1919. (From the Association.)
Bound Brook Oil-less Bearing Company, Booklet of Oil-less Bushings. Bound Brook, N. J., 1918. (From the Company.)
Canada Department of Mines, Bulletin No. 30. Ottawa, 1919. (From the Department.)
Celite Products Company, Bulletin describing standard engineering practice in insulating various types of furnaces. New York, 1919. (From the Company.)
Chapman Valve Manufacturing Company, Catalogue No. 38. Indian Orchard, Mass., 1919. (From the Company.)
Clarage Fan Company, Catalogues Nos. 6, 11 and 51. Kalamazoo, Mich., no date. (From the Company.)
Clark Equipment Company, Booklet, Putting Mettle into Metal. Buchanan, Mich., 1919. (From the Company.)
Cooper, Hugh L., and Company, Catalogue, Hydro-Electric Developments. New York, no date. (From the Company.)
Dunton, M. W., Company, Booklet, Soldering Kinks. Providence, R. I., 1919. (From the Company.)
Edwards, O. M., Company, Inc., Catalogue W-19. Syracuse, N. Y., no date. (From the Company.)
Foxboro Company, Inc., Bulletin No. 104-1. Foxboro, Mass., 1919. (From the Company.)
Galbraith, C. C., and Son, Inc., Booklet of Steamship and Shipyard Supplies. New York, no date. (From the Company.)
Gem City Boiler Company, Catalogues 419 and 519. Dayton, Ohio, no date. (From the Company.)

Gifford-Wood Company, Catalogue No. 35. Hudson, N. Y., 1919. (From the Company.)

Goulds Manufacturing Company, Bulletin No. 122. Seneca Falls, New York, 1919. (From the Company.)

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BOOK NOTICES.

AIR SERVICE MEDICAL MANUAL. War Department. Air Service. Division of Military Aeronautics. 38 pages text, illustrations, plates, 8vo. Washington Government Printing Office, 1918.

Flying, which has now become one of the important features of warfare, and has found some applications in the arts of peace, involves much danger, from defects of machinery, atmospheric conditions and psychology of the

pilot. It is to the last-mentioned condition that this book is devoted. In each of the countries that were at war recently there is an established medical service. The British have organized their service as practically an independent arm, under a Surgeon General of Aeronautics. The United States service is handled by a division of the office of the Surgeon General of the Army. The book is divided into two parts, Part 1 being a brief statement of general facts, including some account of Langley's pioneer work in the construction and operation of the heavier-than-air machine. Part 2 is a detailed presentation of the facts in regard to the psychical requirements of those who undertake to act as pilots, and gives information as to the methods of testing. The numerous illustrations, many of them from photographs, others sketches, aid greatly in understanding the subject. Among the photographs are several showing planes after fatal accidents. In connection with a picture of the wreck of a plane after falling 500 feet, it is stated that only 8 per cent. of such accidents are due to defects in machines. Ninety per cent. are due to defects in pilots. It is also stated that pilots that are physically disqualified for very high flights can serve with satisfaction on bombing machines, which are usually flown at comparatively low levels.

A claim is made that Germany was the first country to recognize the value of the airplane in war, inasmuch as it is stated that when the Wrights took their biplanes to Europe, the French, English and Italians regarded the possibilities of flight only from a "sporting" point of view, but the Germans took up at once the warlike application of the machine. Apart from the fact that balloons had been used for such purposes at least as early as the War of Secession, it is not true that the ingenuity of the German had outdistanced the United States for the Wrights did not take their planes to Europe until 1903, and President McKinley, in 1898, taking note of the success with the model "aerodrome," in 1896, suggested to Langley that he should take up the construction of a man-carrying plane, because he (McKinley) saw the "great possibilities of a flying machine as an engine of war." ("Langey Memoir on Mechanical Flight," p. 124.)

HENRY LEFFMANN.

COURS DE CHIME A L'USAGE DES ÉTUDIANTS P. C. N. ET S. P. C. N. By R. Forcrand, University of Montpellier. 2nd edition, two volumes, 8vo, totalling 954 pages of text. Tables of Contents, but no index. Paris, Gauthier-Villars et Cie. List price, 32 francs; temporary rate, 64 francs.

The shortcomings of this work to which the reviewer deems it proper to call attention may be due in part to the stress and storm under which it was written, but probably largely to the purpose, as avowed, that it is intended for students competing for special certificates. This latter condition will always limit a writer's field.

So far as the work in general is concerned, it may be said that it contains a good deal of information within its almost one thousand closely printed pages. About seventy pages of the inorganic portion are taken up with generalities, most of which material is somewhat similar to the introductory matter of the manuals of chemistry half a century ago, termed often "Chemical Physics." Of physical chemistry, in the sense in which the term is understood to-day, there is but little. A brief notice is given of the phase rule, but

the important subject of hydrogen-ion concentration is not mentioned. In the section of the cyclic compounds, the theories of benzene and of the interesting stereochemistry of these substances are not presented. The author seems indeed to have a strong feeling against reference to German scientific works, for Kekulé and Fischer are not mentioned in connection with the lines of work that they have so brilliantly illuminated. In the section of sugars, levulose is termed l-fructose instead of d-fructose. The relations of colloid chemistry and catalytic action, now so important and interesting, are touched but little. In the classification of the elements, the author uses the division into metalloids and metals, though he shows by several statements that this classification is unsatisfactory. A considerable part of the second volume is taken up with methods of analysis and stoichiometry. Carbon and its oxides are described in connection with organic chemistry, a plan which seems to the reviewer to be of doubtful value.

The lack of an index is very exasperating.

HENRY LEFFMANN.

MESURES PRATIQUES EN RADIOACTIVITÉ. Par W. Makower et H. Geiger, Traduit de l'Anglais, par E. Philippi. 175 pages, index and contents. 8vo. Paris, Gauthier-Villars et Cie. Price 16 francs.

This is a translation of the authors' book entitled "Practical Measurements in Radioactivity" issued in 1912. The original is not at hand, so comparisons cannot be made to determine the accuracy of the translation, but inasmuch as both authors probably understand French, and communications between Paris and London are now rapid and convenient, it is not likely that any important error has occurred; moreover, the translation of simple categoric statements such as make up the greater portion of a work of this type is not difficult. The advisability of translating a book seven years old (the preface to the English edition is dated 1912) without bringing the matter up to date is questionable. No attempt has been made by the translator to cover the literature that has appeared since the publication of the original, at least there is no reference later than 1912, and no translator's preface or even any note or suggestion by him. An appendix giving references to dealers that can furnish materials or apparatus for studies in radioactivity contains six names, of which three are German firms. So far as the matter of the book is concerned, it is presented in a concise clear form, illustrated with numerous simple but satisfactory drawings, and printed on good paper and with clear type.

HENRY LEFFMANN.

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Walrus Hide as a Metal Polisher. (*Brass World,* November, 1919, vol. xv, No. 11, p. 326.)—The Arctic is populated with herds of walrus, somewhat similar in appearance to the seal but larger.

The walrus runs from 12 to 15 feet in length and weighs between 1500 pounds and a ton. His tusks measure 10 or 20 inches long. To-day, in addition to certain other uses, it is found that walrus leather, on account of its tough fibre and extra thickness, is superior to any other medium for polishing metals.

Closely and firmly grained, the tough flexible fibre of this leather will hold in its meshes such materials as pumice, emery, crocus and other abrasive or polishing substances. When its own abrasive qualities are added we have a medium which will produce on any metal a clean and smooth surface, durable and brilliant.

The hide of the walrus runs anywhere from ½ to 1½ inches in thickness. In fact, so variant will a single skin be that the trade has built up the custom of quoting thickness by measuring a specified point at the middle of the back. But a wheel cut from any part of a good skin, regardless of what the local thickness be, gives a solid polishing surface of commensurate width and insures an even friction on any surface to which it is applied. The skin can also be cut in strips and mounted on wooden wheels.

R.

CURRENT TOPICS.

The Wood Alcohol Peril.—Methyl alcohol is found abundantly in commerce in two forms, the crude "wood spirit," which contains acetone and tar products, and the highly rectified form, which contains no appreciable impurities, except a small proportion of water. The crude form has a characteristic disagreeable odor, and does not seem likely to be used as a beverage even by inadvertence, much less by intention. The pure form has but little odor and mixed with water and colored may be drunk without warning. This form has long been sold for manufacturing purposes under misleading names, such as "Columbian spirit" and "Colonial spirit," the latter term being especially objectional on account of liability to be confused with "Cologne spirit," the most highly rectified form of grain alcohol commonly found in commerce. As even the purified methyl alcohol was much cheaper than tax-paid ethyl alcohol under the pre-war rates and was not subject to Government control, the temptation to use it in many preparations, such as varnishes and medicines, was very great, and shortly after it began to be a commercial article cases of poisoning began to occur. The earlier cases were mostly of slow poisoning, that is, due to the drinking or inhalation of small amounts at frequent intervals, and the most prominent symptom was blindness due to organic changes in the nervous supply of the eye. Taken in larger doses it acts as powerful poison, often with fatal results.

Attention has lately been directed to the subject, owing to the many cases of acute poisoning caused by the substitution of methyl alcohol for ordinary alcohol, on the part of those who have the drink habit. So far the data have been principally set forth in newspaper accounts and the exact analytic results have not been available, but Dr. Reid Hunt, now at the head of the Division of Pharmacology at Harvard University, prepared for the *Amer. Chem. Soc. News Service* (Bulletin 251) some important and interesting facts. He states that "wood alcohol" has become known as the "American poison" on account of the numerous cases that have been reported in this country. It was shown in a trial some years ago that manufacturers of flavoring extracts had been approached by dealers in wood alcohol and urged to make their preparations with it. The fact that already at that time the bottles bore the label "poison" was explained as a ruse to prevent the Government from placing an internal revenue tax upon wood alcohol.

It is interesting to note that when methyl alcohol was first

brought into general notice (many years ago), Dr. Benjamin Ward Richardson, a prominent English physiologist, basing his opinion on analogies then generally accepted, stated that the substance probably would come into general use as a substitute for ordinary alcohol on account of its more transient effect.

Individuals differ considerably in their susceptibility to wood alcohol; some die or become blind from amounts which seem to do no harm to others. This is true, however, of all poisons. Death or blindness has resulted from two teaspoonfuls and one or two tablespoonfuls of the poison. Sixty to seventy-five of those taking four ounces, that is, a quarter of a pint or half a glassful, have died or become permanently blind. That wood alcohol is properly placed in the list of deadly poisons is evident from the fact that the mortality from arsenic poisoning is only fifty to seventy-five per cent. and that from mercury dichloride even less. Of a group of 130 men who drank a mixture of wood and grain alcohol all but 32 died or became blind.

Crude methyl alcohol is one of the ingredients of denatured grain alcohol, and as this article is sold at less than a dollar per gallon against about eight times that sum for beverage alcohol under present tax laws, the temptation to use the impure liquid is very great. It is claimed by some that many of the recent cases of methyl alcohol poisoning have been of this type, but until scientific reports are available, positive opinion on this point must be reserved. A striking fact is that in many of the States in which prohibition has been established for years, scarcely any cases of wood alcohol poisoning have been reported.

In a case of poisoning recently reported (*Jour. Amer. Med. Assn.*, January 3, 1920, p. 25) a portion of the liquid remaining in the bottle was found to contain 87 per cent. methyl alcohol.

H. L.

The Fuel Problem.—The dominance of oil as a fuel grows apace. A very interesting review of the question is presented by Professor Chester L. Jones, of the faculty of the University of Wisconsin, but at present Commercial Attaché to the American Embassy at Madrid. The article entitled "Caribbean Petroleum" appeared in *Oil News* (December 20, 1919), and calls attention to the efforts steadily pursued by the British to secure control of oil fields, and points out that the United States should make efforts in the same direction, and especially to prevent foreign control of the oil sources in the West Indies. Oil-burning steamships are rapidly replacing those using coal, and if improvements in the Diesel engine continue, even steam-driven ships may find competition too severe. A Scotch ship with Diesel engines has just been turned out, which, it is estimated, can run from London to Australia and half way back on one loading of oil. A report on the *Lusitania* some months before it was sunk stated that if

oil could be used as fuel, ninety per cent. of the firemen could be dropped, and it is further stated that the *Mauretania* could be navigated with 27 firemen in the place of over 300 now employed. A ton of oil takes five cubic feet of space less than a ton of coal, and produces more steam. Oil is not subject to shifting in rough weather, and the machinery does not need any more repairing than with coal. As oil increases the ship's steaming radius, the maintenance of fuel stations is less exacting.

In 1907 Great Britain and Russia made a treaty dividing Persia into "sphers of influence," Russia taking a northern portion and Great Britain a southern, leaving a small middle area for the Persians. The southern area, which it seems has lately been confirmed by a new treaty, contains the oil sources, and this is, of course, the secret of the British action. Notwithstanding Great Britain's immense possessions, these include few oil lands, and hence the present activity of that nation.

Professor Jones states that all around the Caribbean area are indications of undeveloped oil sources, and three are now producing the material. Trinidad delivered over one million and a half barrels in 1917, and a larger yield is reported for 1918. In Venezuela an oil region is developing around Lake Maricaibo. A British company has a concession in Venezuela covering over six million acres.

In this connection some statements that have appeared in the *Mexican Review* (vol. iii, 1919, No. 7, p. 10) are interesting. They relate to the business of the Royal Dutch Shell, as it is now known in the stock market. The "Shell Transport Company" was formed about twenty years ago with a capital of nearly $10,000,000. Its issued capital is now over $50,000,000 and the market value of the shares is about $350,000,000. About twelve years ago the interests of this company were fused with the Royal Dutch Petroleum Company and the assets of both companies were transferred to a British company (The Anglo-Saxon Petroleum Company) and a Dutch company. Of the shares 60 per cent. are held by the Royal Dutch and 40 per cent. by the Shell. The properties of the concern are in Dutch Indies, Rumania, Russia, Egypt, Mexico, Sanawak and the United States.

Sir Marcus Samuel is Chairman of the Shell Company. For sometime past the company has paid dividends of 35 per cent. Its affairs have lately been much discussed in financial circles, because of an expected acquisition of a big interest in the Mexican Eagle Oil Company which has an issued capital of $25,000,000 and declared last year year a dividend of 25 per cent.

H. L.

A New Commercial Sugar. (*Information Circular,* U. S. Dept. of Agriculture.)—The sugar question has become one of the most important phases in the high cost of living. Not only is the price

high, but the supply seems to be far below the requirements of the people. The United States has for many years had the largest consumption among all countries, the ratio being usually over 80 pounds per capita. Starch-sugar has been manufactured in large amount as a substitute for sucrose, but has not been entirely satisfactory for some of the important table uses. The U. S. Department of Agriculture has been for some time investigating proposed substitute sugars and has found the promising one to be maltose, that is, the sugar of malt. Malt is sprouted grain, in which the starch has been more or less converted into a sugar having the same chemical composition as cane sugar, but not identical with it. It has long been known but only recently has it been considered for specific manufacture on the large scale. Two factors have contributed to this result. The establishment of national prohibition will allow a considerable volume of grain that would otherwise be fermented to be utilized, and the plants necessary for the manufacture of the sugar will be already in part at hand in the breweries that will be no longer used for making malt liquors. All the important cereals can be used in the process. The principal installation that breweries will need will be vacuum evaporating pans, which are well-known forms of apparatus. Malt syrup has much resemblance to maple syrup, its use on the table may not be as convenient as common sugar, but it is an excellent substitute, as it has the same caloric value. For cooking and baking purposes, and for some forms of candy, it is in some respects superior to the common form. It is now being used largely in baking and soft-drink plants. It is now quoted in recent papers about 9 cents per pound in large lots. As yet, owing to the absence of any appreciable demand from housewives, grocers are not carrying the article, but it is likely that as its merits become widely known it will be as familiar as corn syrup.

Although the present propaganda is principally due to the cane sugar shortage, yet the new sugar is likely to find wide use in many ways, even in the household, as it is an excellent, wholesome syrup of delicious flavor. H. L.

Académie Royale de Belgique. (*Bulletin de la Classe des Sciences*, 1919, No. 1.)—This, the first number published after the retreat of the Huns from Belgium, fairly throbs with historic interest. At the meeting of January 4, 1919, in Brussels, the Director for 1914, M. P. Pelseneer, said in his address: "Since the last time we were assembled events of unparalleled gravity have come to pass. In contempt of treaties a nation claiming to be civilized attacked without motive a little people, both peaceful and inoffensive, of whose neutrality it was a guarantor. Entire regions have been sacked, civil populations have been massacred, cities have been destroyed or set on fire with their treasures of art or ancient libraries,

thousands of families are in mourning." He pays tribute later to "our powerful Allies who fought at our side for the same ideal."

In the correspondence is a communication from the University of Ghent to foreign universities directing their attention to the work of destruction carried on in that city by the agents of Prussian militarism aided by official representatives of learned Germany.

A "Brief Report on the Condition of the Palace of the Academies after the Departure of the Germans" throws vivid light on the Kultur of the invaders. A caretaker entered this building in Brussels a few days after the Armistice and was met by an overpoweringly vile smell. Two decomposing human bodies were found in the basement. The secretary describes his first visit to the former seat of the Academy of Sciences on November 18, 1918. "With some of my employés I made a rapid visit with nose and mouth covered by protecting material. A dreadful stench reigned everywhere. Neither pen nor pencil can give an idea of the abominable scene our rooms presented. From the very door of the vestibule of the left wing we had to hunt for places to put our feet in order to avoid stepping in excrement. Everywhere was the same filth, the same disorder, the same destruction—broken panes in the windows, the bronze and copper parts of doors carried off. The libraries were topsy-turvy; there were many gaps on the shelves."

An official pig-pen was found in the garden. It is not known what kind of shame hindered the Germans from lodging its inmates in the interior of the Palace, an act which would hardly have changed the appearance of the latter. The products, however, of the piggery were found as hams and pieces of bacon in the chamber of the Royal Historical Commission, which was transformed into a butcher shop.

A series of a dozen reproductions of photographs displays in lasting form to the scientists of the present and of the future the condition of the various rooms of the Palace. The "Salle américaine" containing the publications of the learned societies of the United States was completely emptied. The books which were dumped in the attic are gone.

In its last pages the bulletin reverts to its pre-war scientific aspect where is found a discussion of certain algebraic curves by M. M. Stuyvaert.

G. F. S.

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MOTOR FUELS.*

BY

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INTRODUCTION.

One of the important factors in our present system of transportation is the use of vehicles propelled by internal combustion motors. The use of automobiles and motor trucks has developed to such a stage that they may be regarded as practically indispensable and people in general are looking forward to wider use of this type of mobile equipment rather than anything in the line of restriction. The fuel upon which these motors are dependent is, however, one that is obtained from a raw material which is drawn from comparatively limited natural resources.

The term "motor fuel" is a broad one designed to include a wide range of products capable of furnishing power in internal combustion engines. At the present time, however, "motor fuel" actually means gasoline, a product principally derived from crude petroleum. The production of crude oil has increased steadily throughout the period of years during which the automotive industry has been developed, but the rate of increase has been relatively small. The production of gasoline has increased much more rapidly than the production of crude oil, but even this has not been comparable with the growth of the use of motor-

* Presented at a meeting of the Section of Physics and Chemistry held Thursday, December 11, 1919.

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propelled vehicles. Consequently a real problem exists in the matter of conservation of petroleum-derived motor fuel and the Bureau of Mines is endeavoring to promote measures favorable to more efficient production and is also working indirectly toward the development of satisfactory substitutes to be used in place of the present types of gasoline.

The present paper does not attempt to furnish an adequate discussion of this problem nor is it devoted particularly to desirable measures in the direction of conservation. The object has been to provide information of general interest concerning the present motor fuel situation with the hope that sufficient interest will be aroused to aid in supporting measures necessary for the more efficient utilization of one of the nation's most important resources.[1]

SCOPE OF THE PRESENT PAPER.

The material included in the present paper has been divided under four general heads which are treated in the order stated.

First, information regarding the production and use of gasoline.

Second, information regarding the marketing of gasoline.

Third, information regarding the physical and chemical properties of gasoline and the quality of the products marketed in the calendar years 1917 and 1919.

Fourth, information regarding present tendencies in the development of substitutes for gasoline.

PRODUCTION AND USE OF GASOLINE.

Before discussing the production of gasoline it seems necessary to attempt some sort of a definition. This is not an easy task and the following statement, taken from the 1916 Webster Dictionary, is hardly adequate for present purposes: "Gasoline; a volatile, inflammable liquid used as a solvent for oils, fats, etc., as a carburetant and to produce heat and motive power." The author is venturing the following definition as covering the present understanding of the word: "Gasoline is an inflammable, relatively volatile liquid, derived from crude petroleum or similar in

[1] The material included in the present paper has in large part been taken from the manuscript of a bulletin by H. H. Hill and E. W. Dean which is to be printed at an early date.

properties to petroleum derivatives, and containing a sufficient proportion of low-boiling constituents to permit the starting of an internal combustion motor under moderately unfavorable conditions."

The principal reason for venturing this definition is to permit the making of a distinction between the words "gasoline" and "naphtha." Naphtha is a petroleum product that is generally, though not invariably, less volatile than gasoline but which is chiefly distinguished by a lower content of low-boiling fractions. In other words, naphtha is gasoline minus the major portion of fractions distilling below the boiling point of water.

METHODS BY WHICH GASOLINE IS PRODUCED.

"Straight Refinery" Process.

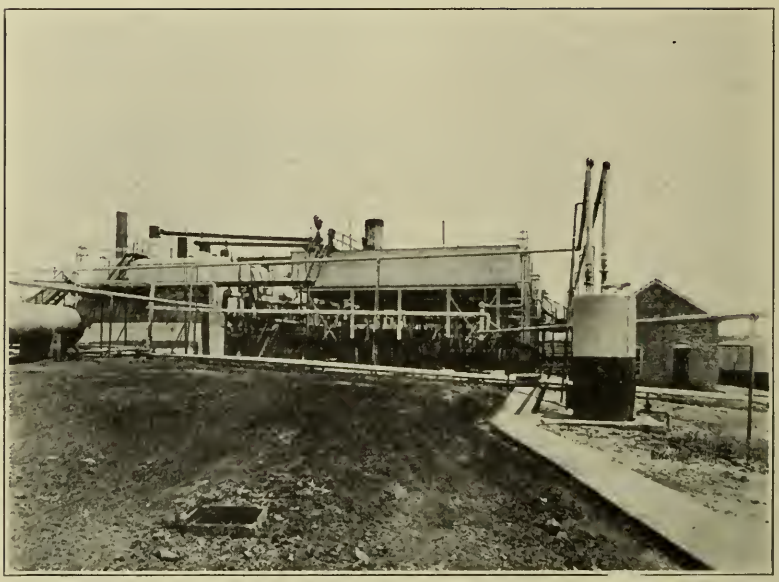
The oldest, and even at present the most important, method of producing gasoline is one involving distillation from crude petroleum. This method is frequently called the "straight refinery" process and gasoline produced by it is termed "straight refinery" or "straight run" gasoline. The basic process is that of fractional distillation, which involves separation of products having different ranges of boiling points. The process, as conducted in commercial practice, varies in a great many details and a discussion of these variations is beyond the scope of the present paper. The following brief description covers perhaps the most common general procedure:

Crude oil is distilled in cylindrical, horizontal stills which are heated either by coal or oil. The vapors pass through condensers and the liquid products are run into receiving tanks. Figure 1 shows a battery of crude stills with condensers and receiving tanks.[2]

The products separated from the crude oil by this primary distillation is in the refinery generally called "crude naphtha" or "crude benzine." The next process of treatment is usually a chemical one which is principally intended to improve the color and odor of the product. Crude naphtha is pumped into lead-lined agitators and is there treated, first with sulphuric acid, then with caustic soda solution, and finally with water. The stirring is

[2] The type of still represented in this illustration lacks the fractionating column employed in some of the more recent installations.

FIG. 1.



Southern Oil Corporation, Yale, Oklahoma. Crude oil stills, condensers and receiving tanks.

FIG. 2.

Southern Oil Corporation, Yale, Oklahoma. Agitators for chemical treatment of gasoline.

usually accomplished by blowing air in at the bottom of the agitator tank. Figure 2 shows three agitator tanks of this type.[3]

The final process in the refining of gasoline is a redistillation of the chemically treated crude naphtha. This distillation is generally carried out in so-called steam stills. Steam stills sometimes are heated entirely by closed steam coils, sometimes partly by fire while live steam is blown through the hot liquid. Steam stills

FIG. 3.

Cosden and Company, Tulsa, Oklahoma. Steam stills for redistillation of gasoline.

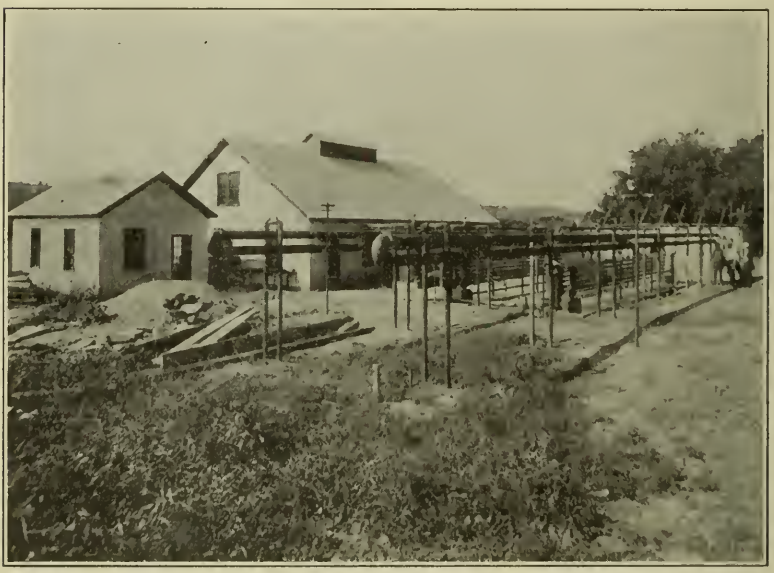
are generally, though not invariably, equipped with fractionating towers and are often operated in batteries which permit continuous rather than "batch" distillation. Figure 3 shows in the foreground steam stills of the type in which heat is supplied by closed steam coils. It will be observed that these stills are equipped with large fractionating columns.

The properties of the gasoline produced by the straight refinery

[3] Another type less commonly used involves the so-called continuous process in which crude naphtha passes through tanks containing respectively acid, water, alkali, and water. The continuous method has some advantages but according to the writer's observation is less extensively employed than the non-continuous type involving stirring by means of air.

process are subject to considerable variation and are controlled in part by the physical and chemical nature of the crude oil from which it is derived and in part by the procedure employed in the refinery. Straight refinery gasoline is composed chiefly of so-called saturated hydrocarbons, that is, hydrocarbons which are not chemically active. Most of the chemically active products which may be present in the crude naphtha from the primary

FIG. 4.



Carter Oil Company, Sistersville, West Virginia. Casinghead gasoline compression plant.

distillation are removed by chemical treatment with sulphuric acid. The property chiefly controlled by the refining process is the "end point" or upper boiling limit of the gasoline, which is fixed so as to separate the more volatile fractions from those generally marketed as kerosene or lamp oil.

"Casing-head" Gasoline Process.

A considerable proportion of the present supply of motor gasoline is derived not from crude petroleum but from natural gas. Gasoline from this source is commonly called "casing-head gasoline," due to the fact that before its commercial separation

was in vogue it was discovered as a condensate around the heads of well casings. Natural gas frequently contains appreciable quantities of liquid hydrocarbons which, although of relatively low-boiling point, can be readily separated. Two types of process to effect this separation are in general vogue, the older, and perhaps still the more important, being the so-called compression process. This process is usually operated according to the following general scheme: Natural gas is compressed under a moderate pressure and then cooled. Subsequently it passes through a second set of pumps which brings it up to a high pressure. Cooling after this second compression effects separation of the liquid hydrocarbons. This type of process is used only for natural gas of relatively high gasoline content. Figure 4 represents a plant operating the compression process. Most of the equipment is inclosed and cannot be observed, but the cooling coils appear in the foreground.

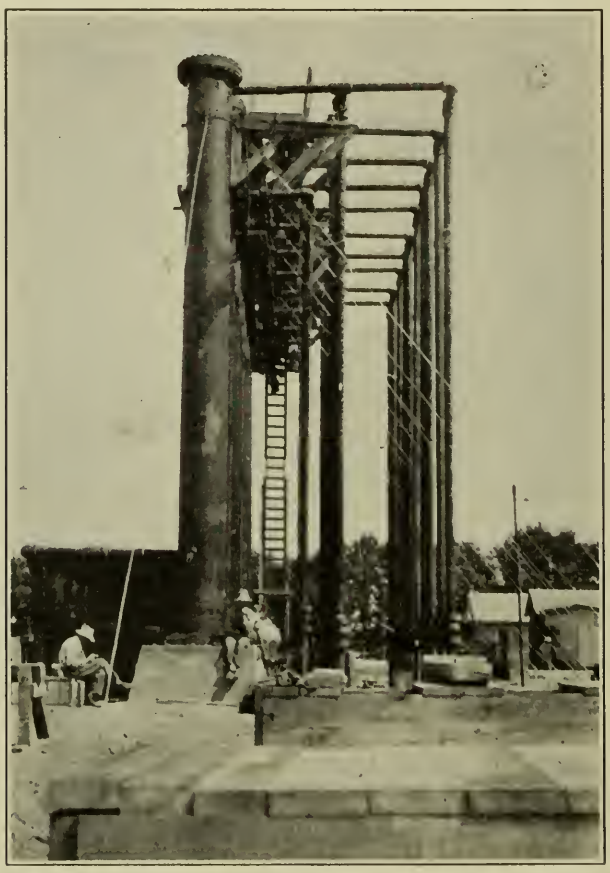
The other process is the absorption type which involves washing the natural gas with either a heavy naphtha or a high-boiling petroleum oil, thereby dissolving out the bulk of the liquid hydrocarbons. When naphtha is used as the absorbent a product is obtained from the absorption towers that is usually marketed without subsequent treatment. If a more efficient absorbent such as so-called straw oil or mineral seal oil is employed, the casing head gasoline must be separated by distillation. Figure 5 shows one of the first of the plants operating the absorption process.

Casing-head gasoline produced by the compression process is somewhat more volatile than that produced by the absorption process, but either product has too high a vapor pressure to permit safe handling or transportation.[4] The usual practice is to blend this gasoline either with naphtha or with high end point gasoline, after which it can be shipped and handled with a reasonable degree of safety. Casing-head gasoline blends were unfavorably regarded by users when first put on the market, but this was due more largely to improper methods of blending them than to any inherent bad qualities of the product. The blended casing-head gasoline now marketed is probably rather more satisfactory in use than the so-called straight refinery gasoline of equivalent average boiling point, this on account of its greater ease in starting

[4] The Interstate Commerce Commission has issued regulation specifying the maximum allowable vapor pressure for gasoline.

a cold motor. Statistics have shown that approximately 10 per cent. of the nation's supply of gasoline is of the casing-head variety and due to the necessity and desirability of blending with less volatile petroleum distillates it is probable that the proportion

FIG. 5.



Ohio Fuel Supply Company, Homer, Ohio. Casinghead gasoline absorption plant.

of marketed gasoline, containing products from natural gas, is several times this figure.

Cracking Processes.

Another recently developed method of producing gasoline is the so-called cracking process which has received a considerable

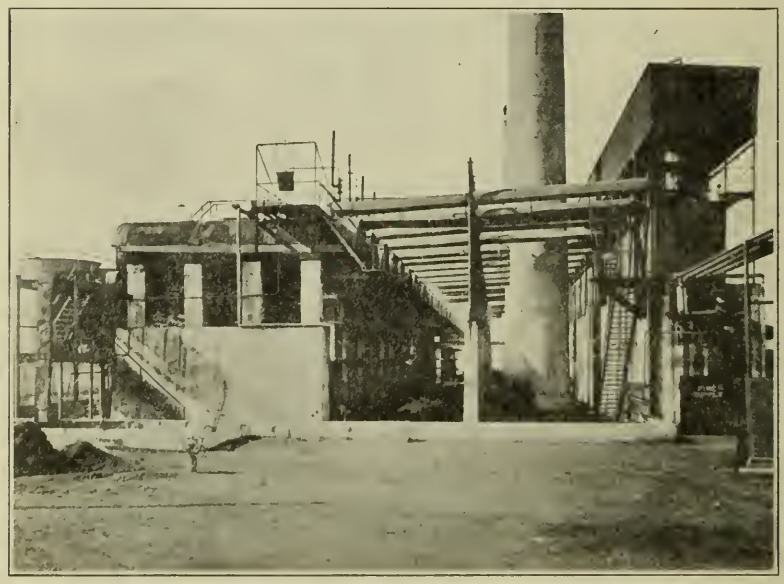
amount of publicity during the past few years. The basic principle of the cracking process is one with which all chemists are familiar, namely, that if organic compounds are heated at sufficiently high temperature they decompose with the formation of other compounds, a large percentage of which are of smaller molecular weight and lower boiling point. The cracking process has been used in the petroleum industry since the early days of its development, chiefly for the production of kerosene from the higher boiling fractions usually classed as fuel oil. This older process was conducted at atmospheric pressure. It appeared, however, that satisfactory yields of gasoline could not be obtained under these conditions as the hydrocarbons from which it is derived tended to vaporize before decomposing. In order to produce gasoline by the cracking process it is necessary to maintain the distillation system under pressure, thereby permitting the attainment of a high temperature before vaporization occurs. Cracking has also been effected by the scheme of passing liquid or vaporized oil through superheated tubes. Numerous types of gasoline-cracking processes have been developed, some of the pressure-distillation type, others of the tube type. At present the pressure-distillation type is the only one that has been developed on an important commercial scale. The process most commonly used is that of Burton, which was developed by the Standard Oil Company of Indiana and which is operated by this company and by various others, mostly of the Standard group.

Figures now available have indicated that approximately 10 per cent. of the nation's supply of motor fuel is derived from cracking processes. Cracked gasoline is similar to straight-run gasoline as regards physical properties, but there is an essential chemical difference due to the fact that the cracking reaction produces a considerable percentage of olefin or unsaturated hydrocarbons. The content of these hydrocarbons is commonly estimated by observing the percentage of the gasoline absorbed by ordinary concentrated sulphuric acid. This does not accurately measure the content of olefins, but for general purposes, however, the term "percentage of unsaturation," meaning percentage absorbed by sulphuric acid, is a convenient one to use. Untreated cracked distillates may have "percentages of unsaturation" as high as 40 per cent., a more usual figure, however, being 20 to 25 per cent. Cracked gasoline is usually marketed in the form of

mixtures with straight refinery and casing-head gasoline, these mixtures rarely being more than 12 per cent, unsaturated, which indicates that the products of the cracking reaction are blended with at least an equal amount of casing-head or straight-refinery gasoline.

Figure 6 shows a battery of Burton stills. These stills are distinguished from the more common types of refinery equipment

FIG. 6.



Standard Oil Company of Kentucky, Louisville, Kentucky. Burton gasoline cracking stills.

by the fact that they are operated under pressure and that they are equipped with special types of fractionating towers.

STATISTICS REGARDING THE PRODUCTION AND USE OF GASOLINE.

Statistical information is frequently uninteresting and unless figures are carefully interpreted it may be misleading. As regards the production and use of gasoline, however, the information now available is so definite and impressive that misunderstanding is practically impossible. In the present connection it is interesting to present data regarding the magnitude of the nation's production and consumption of gasoline, the relation between production

of gasoline and production of crude oil, which is the principle raw material from which it is derived, and the relation between production of gasoline and the magnitude of the most important outlet of consumption, which is the automotive engine. It is also interesting to note certain seasonal factors which have to do with the production, consumption and storage of gasoline.

TABLE I.

Showing Increases in the Annual Production of Gasoline in the United States.

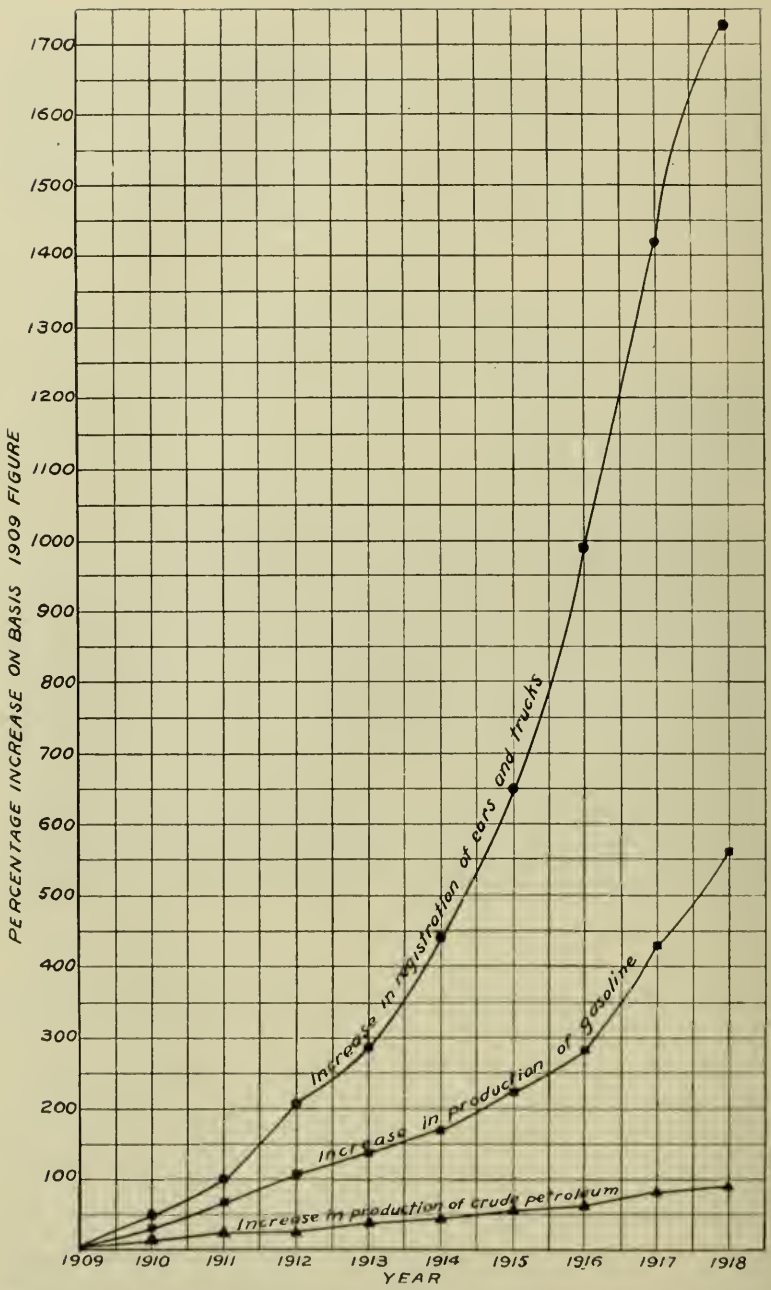
Year	Production of gasoline	
	Barrels	Gallons
1909.....	12,900,000	541,800,000
1916.....	49,020,967	2,058,880,614
1917.....	67,870,153	2,850,546,426
1918.....	85,007,451	3,570,312,942

The increase in production of gasoline during the last few years is shown by the figures in Table I.

Assuming that the average refinery price of gasoline during the year 1918 was 18 cents per gallon, it appears that the total value of the year's production of motor fuel is approximately $650,000,000.

An interesting relation may be observed by comparing the increase in production of crude petroleum and gasoline and the increase in number of cars and trucks in use in the country. Figure 7 represents these increases on a percentage basis, the 1909 figures being regarded in each case as the basic ones. It will be noted that during the 10-year period the production of crude oil from wells in the United States increased by about 95 per cent., the production of gasoline by approximately 560 per cent. and the number of cars in service by over 1700 per cent. These figures bring out certain important facts. The production of gasoline has increased at a notably greater rate than has the production of crude oil. In 1909 the yield of gasoline from the crude refined was 10.7 per cent., whereas in 1919 the yield was 26.1 per cent. This increase in the relative amount of gasoline produced from the crude is accounted for in several ways. In the first place, the distillation range of gasoline has been notably

Fig. 7.



Showing relative increases since 1909 in the production of crude petroleum and gasoline and in the registration of motor cars and trucks.

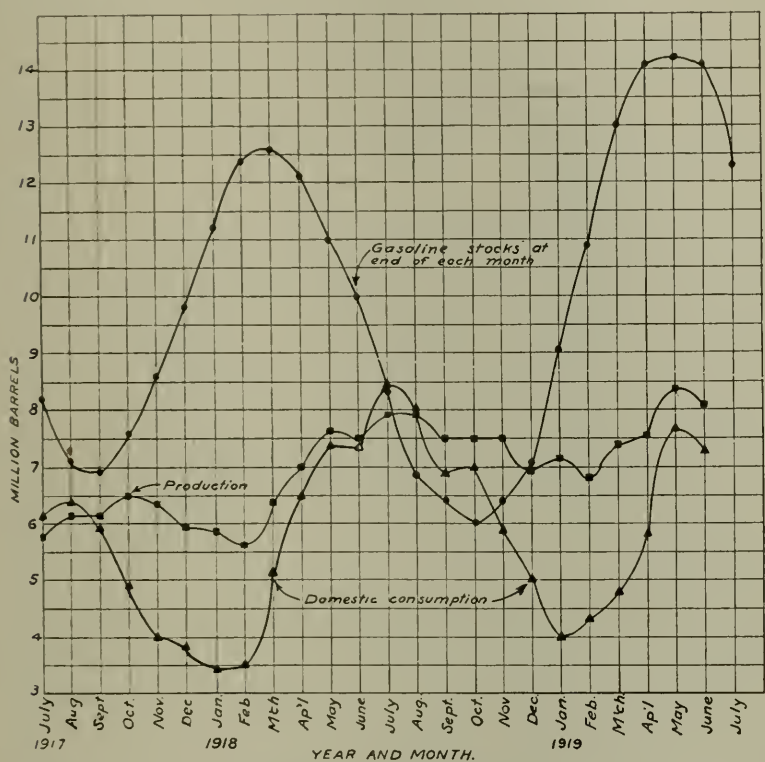
changed, products now on the market being of considerably higher average boiling point than those in 1909. The production of casing-head gasoline and the use of cracking processes have been important factors in increasing the apparent yield of gasoline from crude oil. In addition there undoubtedly have been increases in the efficiency of the conventional types of refinery equipment such as crude stills and steam stills. It may be noted, also, that the average quality of the crude oil produced in the country has probably improved as regards gasoline content. It is a question as to how near the present percentage of gasoline production per unit quantity of crude oil approaches the maximum that is commercially practical. It is impossible to make predictions regarding the future quality of crude oil. As regards efficiency of refinery equipment, it has been estimated that this may be improved on the average by a maximum not over 10 per cent. The production of casing-head gasoline undoubtedly has not reached a maximum but here again it is difficult to attempt an estimate. The use of cracking processes certainly has not developed to the maximum possible extent and the author has in the past ventured to predict that the quantity of gasoline produced from the crude could, if desired, be practically doubled if maximum use were made of this means of production. These estimates have not been strenuously contradicted but the author is frank to admit that his own optimism has decreased considerably since they were offered. It is still believed that the use of cracking processes could double the production of gasoline, but it appears that this is not likely ever to be accomplished as there is a marked tendency for increases in the use of fuel oil, which is the product that must necessarily be sacrificed in case maximum production of gasoline is attained through cracking. It is now believed that the chief limiting factor for the use of cracking processes is likely to be the demand for fuel oil. As regards further increases in the end point of gasoline, considerable doubt exists. Many authorities in the automotive industry claim that the present limits are too high, although this probably means that they are too high for the types of engines that can and will be developed in the reasonably near future. The present considerable demand for kerosene indicates, moreover, that further changes in the quality of gasoline are not likely to occur in the immediate future as raising the end point of gasoline inevitably decreases the production of kerosene.

The fact that the number of cars in service has increased approximately three times as much as the production of gasoline is a fact meriting serious consideration. Although exact data on this point are not available, it is not believed that the average consumption of gasoline per car has notably decreased. The obvious inference is that in 1909 the percentage of gasoline used by automotive vehicles was considerably smaller than the percentage so used in 1918. Inasmuch as the use of gasoline and naphtha for other purposes than internal combustion engines is increasing rather than decreasing, it is entirely reasonable to believe that at no very distant time the demand for gasoline is likely to exceed the supply unless the producers of gasoline add to their already considerable accomplishments in production, or unless the fuel efficiency of automotive equipment is considerably improved. It is realized that the production of gasoline during the present calendar year (1919) has been slightly in excess of consumption, but this is readily accounted for by the fact that the petroleum industry increased its volume of production during the war, whereas the manufacturers of automobiles and trucks have not yet gotten back to pre-war operating efficiency.

Aside from statistical evidence indicating the necessity of conservation, it is interesting to observe certain facts regarding the seasonal variations in production, consumption and storage of gasoline. Figure 8 is of interest, although it may be noted that the facts most clearly brought out are not those indicative of normal tendencies. As regards the production of gasoline it may be observed that there is a slight seasonal fluctuation, refineries working at greater efficiency during the summer than during the winter months. The consumption of gasoline varies notably, due to the fact that automobiles and trucks are less extensively used in cold than in warm weather. The quantities of gasoline stored naturally vary in the opposite direction, the stocks at the refineries increasing during the winter months and decreasing during the warm weather. The curves in Figure 8 illustrate the general tendencies, although there are certain fluctuations in the maxima and minima which were caused by war-time conditions. It is of particular interest to note that stocks of gasoline reached an abnormally low mark during the late summer and early fall of 1918, there being at this time less than one month's supply of gasoline in reserve. This condition was what caused the regula-

tion prohibiting the use of motor vehicles on Sundays during a period of several weeks. It may be observed that although the consumption of gasoline in September, 1918, was less than that of August, which is normal, the consumption in September was also less than that in October, which is unusual. As regards

FIG. 8.



Showing stocks, refinery production, and domestic consumption of gasoline for the period, July, 1917, to July, 1919, inclusive.

the curve indicating quantities of gasoline in storage, it is interesting to observe an unusual situation for the present year. Maximum stocks of gasoline are usually in storage in the early spring, which was the case in 1918. In 1919 a maximum was not reached until May and no important decrease in stocks occurred until July. In July of 1917 and July of 1918 stocks were at a considerably lower level than in July, 1919.

MARKETING OF GASOLINE.

The marketing of gasoline is a subject that is of particular interest but does not, however, permit satisfactory discussion by a chemist. The following observations are presented with a certain degree of qualification. The author feels that the basic data are reliable but does not guarantee his interpretation in all cases. Gasoline marketing practice obviously is not controlled by any simple physical and chemical laws and any general tendencies that may be noted are principally emphasized by exceptions.

The marketing of gasoline generally involves jobbing and retailing organizations which handle the product after it is delivered by the producer. In some cases the three organizations—producing, jobbing and retailing—are entirely distinct, in others they are controlled and operated by a single company. Likewise, there are cases where two of the organizations are under the same general control and the other is separate. As a general rule competition in the retail end of the business is practically unrestricted, producing and jobbing companies selling gasoline freely to independent competing organizations. There are certain exceptions to this and it may be noted that in several cities in the Middle West the retail price is the same as the jobbers' price, which eliminates any profit for the independent retailer who tries to meet the general figure for the locality. This is not, however, a particularly serious matter as the retailer's profit is always small and frequently does not cover losses and the cost of handling. The usual margin is two or three cents a gallon, which is about 10 per cent. of the selling price. In general the small retailer handles gasoline chiefly for the purpose of attracting or retaining customers who purchase other commodities yielding a larger margin of profit. The larger filling stations probably make a fair profit on gasoline, although even here it is safe to assume that the really profitable branch of business is the sale of lubricating oil and occasionally other automobile accessories. It may also be mentioned that the system of retail distribution of gasoline is very highly organized and that customers receive service which is claimed to be the best maintained in any line of business. The author is frank to admit that with the possible exception of tobacco he does not know of any commodity which is as generally available and efficiently dispensed as gasoline.

As regards the price of gasoline, there are no general rules

which can be stated without bringing to mind a host of exceptions. The one generally recognized fact is that the jobber's price for gasoline is generally that fixed by the larger marketing organizations. What actually determines the prices selected by these organizations is something which can be determined only in a very general way and the chief point of importance to the general consumer is that competing organizations generally favor an upward rather than a downward revision.

TABLE II.

Showing Retail Prices of Gasoline in April, 1919, in Several Cities Throughout the Country.

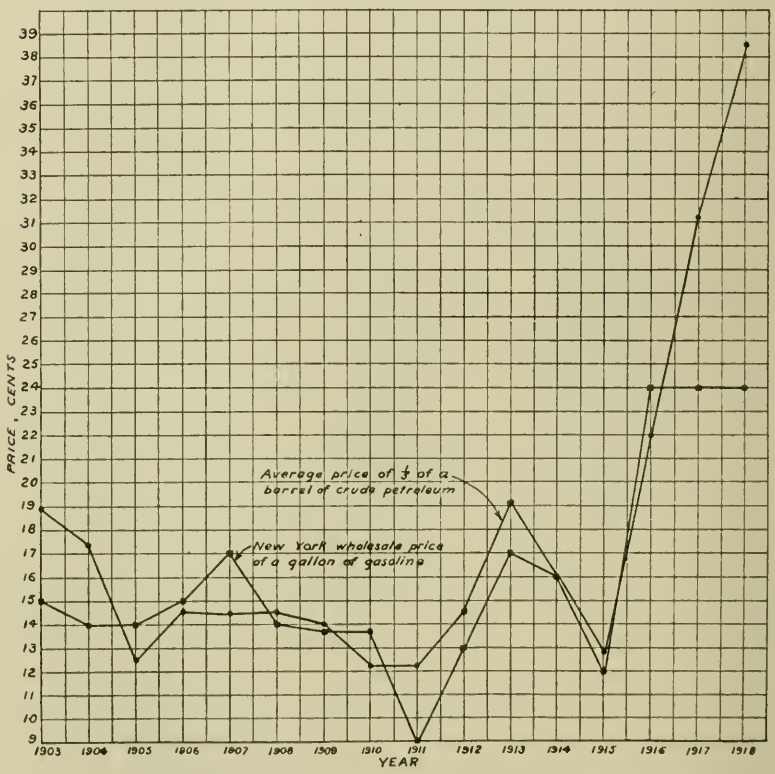
State	City	Retail price (cents per gallon)
Massachusetts	Boston	27.5
New York	New York	27.0
Georgia	Atlanta	26.5
Illinois	Chicago	23.0
Kentucky	Louisville	25.5
Alabama	Birmingham	26.5
North Dakota	Fargo	27.1
Kansas	Wichita	22.7
Texas	San Antonio	24.5
Montana	Missoula	29.0
Colorado	Denver	28.0
New Mexico	Albuquerque	32.0
Washington	Seattle	21.5
California	San Francisco	20.5

The most important general factors regulating the price of gasoline are the costs of transportation from refining centres and the demands of customers as regards volatility range. Gasoline marketed at a considerable distance from centres of supply is more expensive than that marketed in adjacent districts provided the grade demanded is the same. Likewise, districts that are satisfied with motor fuel of high end point generally get it at a more favorable price than similarly located districts that favor a more volatile type of gasoline. Figures in Table II show the retail prices maintained in the spring of 1919 in several cities throughout the country. It will be noted that prices were lowest in the Pacific coast states and in the Mid-Continent states nearest the producing centres, and highest in the Atlantic coast and Rocky Mountain states.

The most important thing to note in regard to the price of

gasoline is its relation to the price of crude oil. Figure 9 illustrates this in a decidedly satisfactory manner. On this diagram are plotted New York jobbers' prices per gallon of motor gasoline and the average prices throughout the country of a fifth of a barrel of crude petroleum. It will be observed that the curves are in general parallel with the single notable exception for the

FIG. 9.



Showing the relation between the price of crude petroleum and the price of gasoline.

year 1911, an explanation for which has not been worked out by the Bureau of Mines, although it seems possible that it may have been due to the fact that the Standard Oil Company was ordered dissolved by Federal injunction at about this time. It may be noted also that since 1916 the price of gasoline has held practically constant, whereas the price of crude petroleum has increased very considerably. This discrepancy is in part due to

the fact that the New York price has held constant, whereas in general throughout the country there has been an increase of 2 to 4 cents per gallon. Even with this increase, however, there would be a tendency for the gasoline and crude oil curves to diverge. A probable explanation of this is the fact that an increased demand for other refinery products has permitted the charging of a lower percentage of operating costs against gasoline than was customary in the earlier period. During the past year the supply of gasoline has slightly exceeded the demand, which is another reason for relatively slight increase in cost. In any event, the important fact is that the price of gasoline has been in general proportional to the cost of the raw material from which it is derived; which indicates that the oil refining industry at least has not been guilty of profiteering.

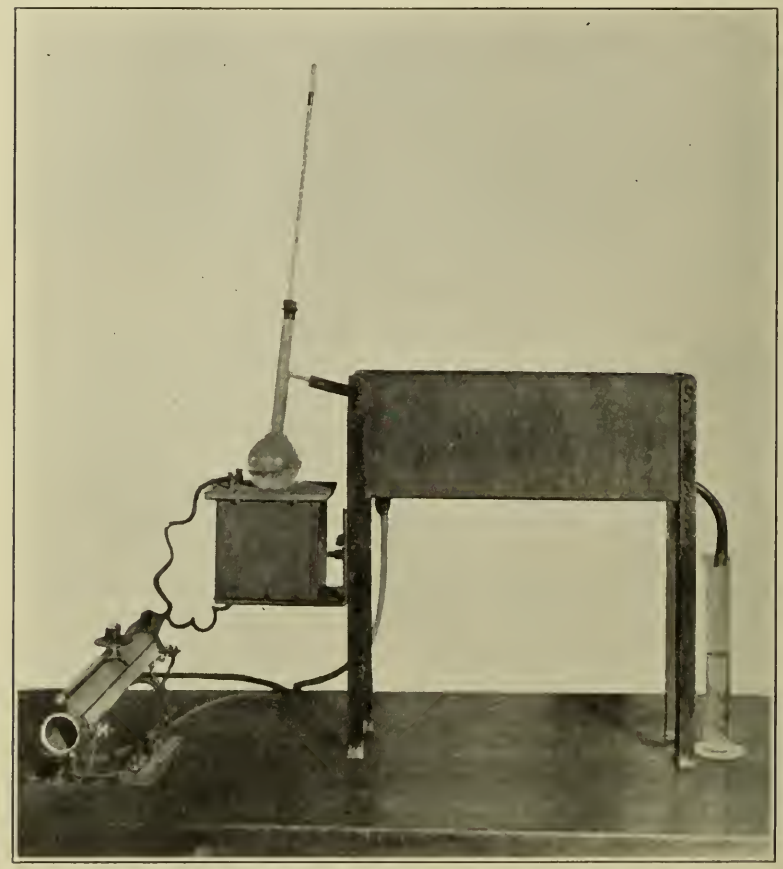
PROPERTIES OF GASOLINE.

The most interesting phase of the subject of gasoline for a chemist is. of course, its physical and chemical properties. Discussion of these, however, is likely to lead to a great many details which are not of general interest and realizing this fact the author has attempted to avoid technical details as far as is consistent with giving a reasonably adequate idea of what gasoline actually is.

The various properties which are commonly studied may be listed as follows: color, odor, "doctor" test for decomposable sulphur bodies, corrosion and gum formation, gravity, unsaturation, acidity, and volatility or distillation range. Of these properties it may be stated that color, odor, the "doctor" test and the corrosion and gumming test are not of sufficient interest and practical importance to warrant discussion in the present paper. The gravity test is one which has been highly regarded in the past but which actually is of minor significance. The present paper undertakes to show why it is of slight use in determining the quality of gasoline. The unsaturation test is of interest because it shows whether or not a gasoline contains products of the cracking reaction. The acidity test is one which covers care in refining and which has been included in government specifications, although its practical value has not as yet been definitely determined. The most important property of gasoline is its volatility, which is indicated by determination of its distillation range. The behavior of gasoline in an internal combustion engine is very largely determined by this property of volatility, which is the basic

one on which gasolines are graded by intelligent refiners. The older system of grading on the basis of gravity still holds to a limited extent but even this is based on the assumption that dis-

FIG. 10.



Apparatus for the analytical distillation of gasoline.

tillation range is a function of gravity, which assumption is correct only when considerably qualified.

VOLATILITY OR DISTILLATION RANGE.

The method for determining volatility involves an analytical distillation under regulated conditions. These conditions and

the nature of the apparatus used have a considerable influence over results and it is, therefore, necessary that tests be made in the same way if figures are to be regarded as comparable. Testing methods were in the past subject to considerable discrepancy, but since the recent recommendation of a certain method by the Bureau there has been a marked improvement in this particular. Practically all specifications are now based on a distillation by the method recommended by the Bureau of Mines, which has been described in various publications.[5] The apparatus used in the test is represented in Fig. 10 and consists essentially of a source of heat, a 100 c.c. distillation flash of specified dimensions, an ice-cooled condenser of specified dimensions, and a 100 c.c. graduate. The method involves heating the gasoline at a specified rate and reading temperatures when the first drop falls from the end of the condenser, when each of the respective 10 per cent. marks is reached, and when the dry point is reached, the latter being taken as the highest temperature obtainable shortly after the flask has apparently boiled dry at the end of the distillation. Of these various readings, the following are usually sufficient to define the distillation range of gasoline; first drop temperature, 20 per cent., 50 per cent., 90 per cent. marks and the dry point. These are the points usually employed in specifications. Figure 11 shows a curve plotted on the limits of the points set by the present government specification for gasoline. It will be observed that each of the ends of the curve is rather definitely fixed by the use of two points. A point for the 50 per cent. mark fixes the intermediate portion of the curve. This, however, is not absolutely necessary as there are inconsiderable possibilities of variation in this point when the end limits are specified.

In discussing the properties of gasoline a figure is sometimes employed which is called the average boiling point. This has not been employed in specifications as yet, but is of some value in providing a single figure to be used as an index in stating the volatility of gasoline. This figure is obtained by adding the first drop temperature, each of the 10 per cent. marks, and the dry point, and

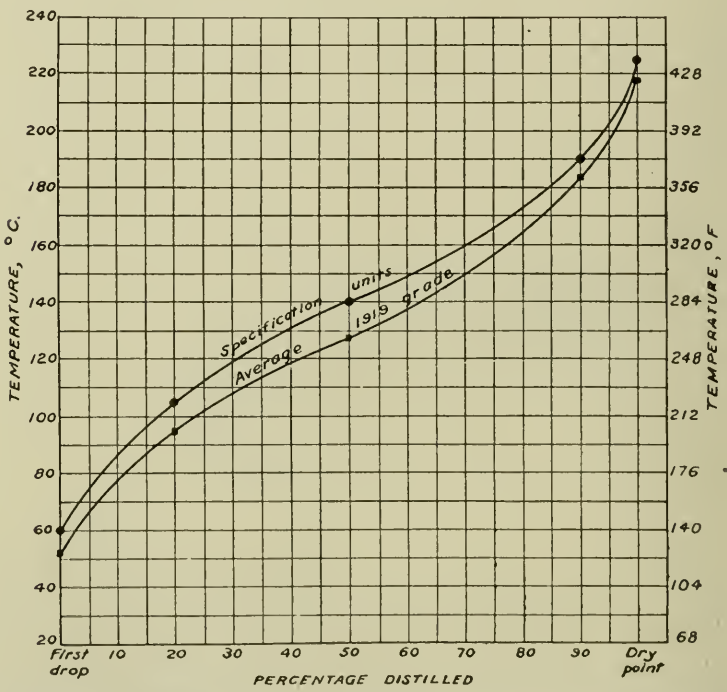
[5] American Society for Testing Materials, Year Book for 1915, pp. 568–569; or Part 1, Committee Reports 1916, vol. 16, pp. 518–521. Dean E. W., "Motor Gasoline, Properties, Laboratory Methods of Testing and Practical Specification." Bureau of Mines Technical Paper No. 214, 1919, 33 pages. Also Technical Paper No. 166 by the same author and with the same title, 1917, 27 pages.

dividing by eleven. This figure provides the same sort of information that would be obtained by means of a gravity test if the gravity test indicated what it is supposed by many to do.

DISTILLATION RANGE OF COMMERCIAL GASOLINE.

Three methods of producing gasoline have been discussed, namely, the straight refinery method, the casing-head gas method,

FIG. 11.

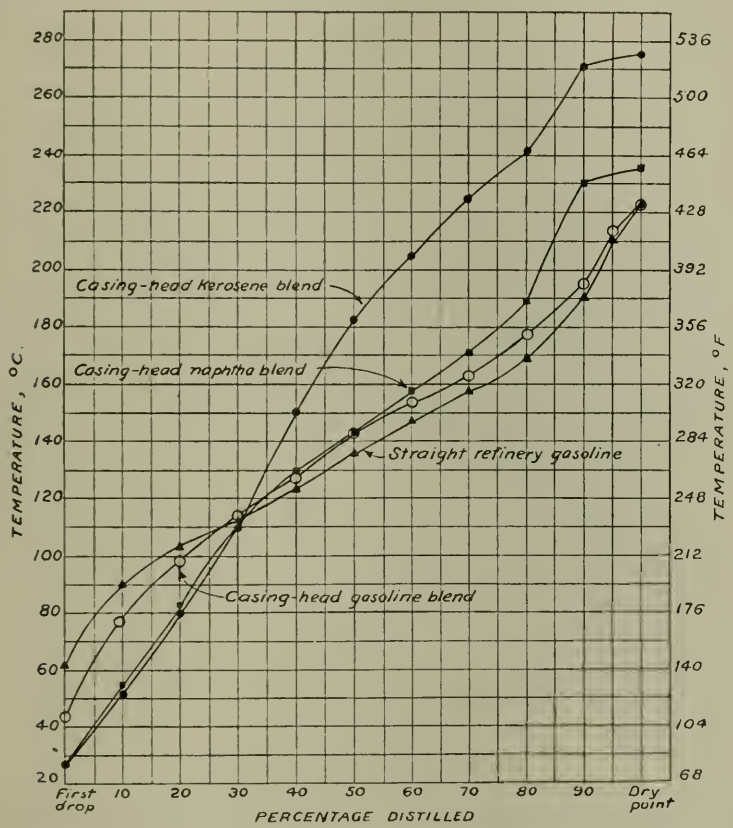


Showing curves representing the distillation limits set by the 1919 Government specification for motor gasoline and the average distillation range of the series of samples collected by the Bureau of Mines in April and May, 1919.

and the cracking method. Gasoline produced by the cracking process has no characteristic properties as regards distillation range. It is, however, frequently possible to distinguish gasoline blended with casing-head products from the straight refinery types. Figure 12 shows an interesting series of curves. One of the samples represented is a product made by blending casing-head gasoline with kerosene. Its distillation range is distinct from

that of any of the other samples. This type of fuel is not regarded as entirely satisfactory. It may be noted, however, that neither the gravity test nor the average volatility figures would distinguish this gasoline from one of the more desirable types. The

FIG. 12.

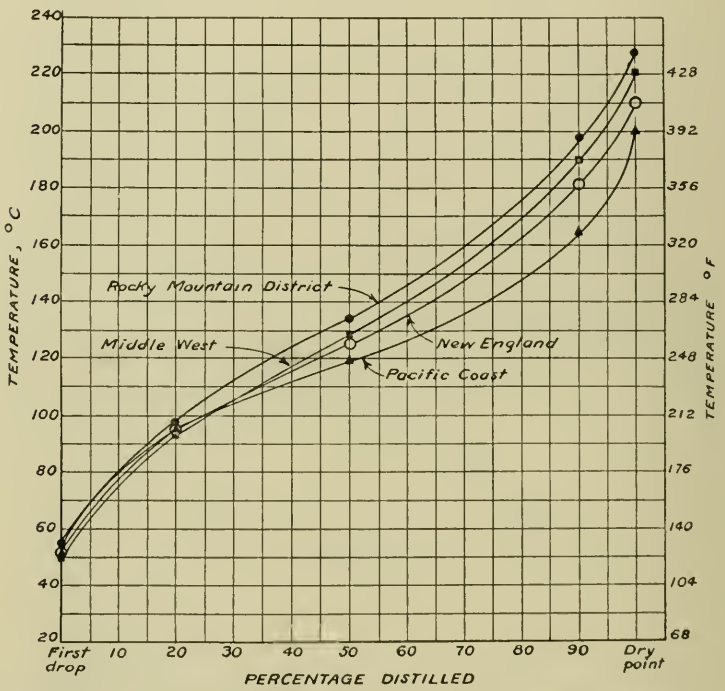


Showing distillation curves of three types of blended casinghead gasoline and straight refinery gasoline.

second sample of the series represented in Figure 12 is one composed of casing-head gasoline, blended with a so-called heavy or high-boiling naphtha. This type of product is notably superior to the kerosene blend but is not entirely ideal as motor fuel, although gasoline of this type is used in large amounts and with reasonable satisfaction. It is believed, however, that the prefer-

able type of casing-head blend is that represented by the third curve which shows the distillation range of a sample made by blending a very moderate quantity of casing-head gasoline with straight refinery gasoline. The curves for the three casing-head blends are shown in comparison with the curve for a straight refinery gasoline. It will be observed that the casing-head blends

Fig. 13.



Showing distillation curves representative of the average grades of gasoline marketed in 1919 in four general sections of the country.

have curves which for the first 20 or 30 per cent. are lower than the straight refinery product. Above this point the curves are higher than the curve for the straight refinery gasoline by varying amounts.

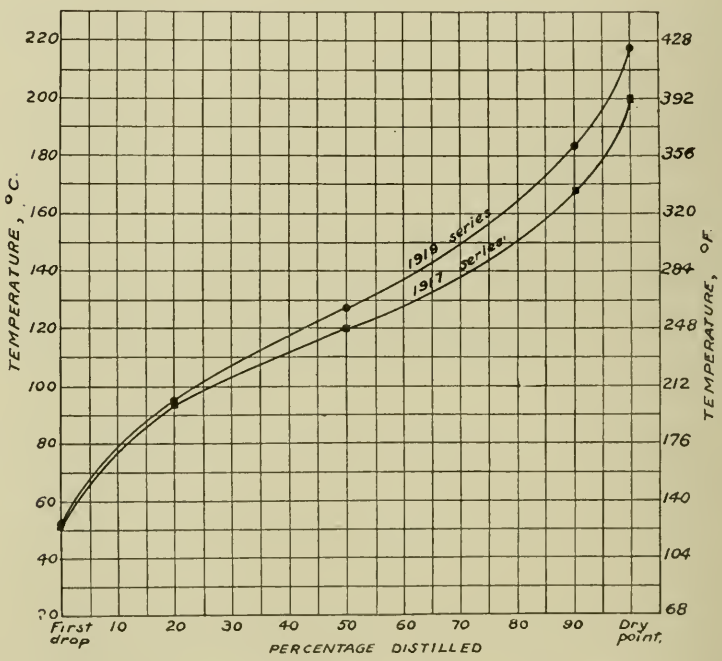
In the spring of 1919 and in the spring of 1917 the Bureau of Mines made surveys of the quality of gasoline sold throughout the United States. Certain of the results of these surveys are of general interest and are briefly discussed. In the first place, it was observed in the course of both surveys that the general quality

of gasoline varied to a certain degree in various sections of the country. The states on the Pacific coast received gasoline of relatively low-boiling range (or high volatility). The states on the Eastern coast were next as regards low-boiling range of gasoline. The Middle Western states received gasoline which was less volatile than that marketed on the Eastern coast, while the Rocky Mountain district received the least volatile grade of gasoline of any part of the country. Figure 13 shows four curves representing four different parts of the country, these curves being based on the average of figures for the samples collected in each of the four districts. It will be noted that as regards the more volatile fractions of gasoline, represented on the lower end of the distillation curve, the differences are slight. Beyond the 20 per cent. mark, however, the curves diverge and there are appreciable differences at both the 90 per cent. mark and the dry point. A similar series of curves was obtained for samples collected in 1917, although at that time the Rocky Mountain district was not homogeneous as regards the quality of gasoline received. A certain proportion of gasoline marketed in this district came from California and was of the same general quality as that marketed on the West coast.

The chief point of interest with regard to these curves is the general change in the quality of gasoline. The boiling range of gasoline has, during the past five or ten years, been increasing notably. In the days when gasoline was a by-product of the refining industry, incident to the production of kerosene or lamp oil, its end point was in the general neighborhood of 300° F. As the demand for gasoline increased, this end point has gradually raised. When the Bureau first began a study of the properties of gasoline, the figures usually maintained were between the limits of 350° F. and 400° F. The end point has continued to increase so that in 1919 the average was about 425° F. As regards the change in quality between 1917 and 1919, the curves in Figure 14 are instructive. These curves represent average figures for all of the samples collected in each of the respective surveys. It will be noted that the first drop and 20 per cent. temperatures are practically the same in both cases but that the curves diverge beyond this point, the difference at the 90 per cent. marks and dry points being between 15° C. and 16° C. This means that the gasoline marketed in 1919 was practically equal to that of 1917 as regards

starting qualities but that the properties controlled by the end point had changed somewhat. Improvements in engine design have undoubtedly made up for a considerable proportion of this difference and the gasoline marketed as present is probably used with fully as great satisfaction as that marketed in 1917. There is some question as to how much higher the end point can be raised

FIG. 14.



Showing average distillation curves for the series of samples of gasoline collected by the Bureau of Mines in surveys made in 1917 and 1919.

and still yield satisfactory results. This is a point concerning which detailed information is lacking. The Bureau believes, however, that in general the grades of gasoline now on the market are being used with a reasonable degree of satisfaction. The practice of the refining companies is to avoid, as far as possible, dissatisfaction on the part of their customers, and if a certain grade of gasoline is subject to too many complaints it is practically certain to be modified. It is realized, however, that the demands of users in different parts of the country are not the same and that

what is regarded as low-grade gasoline in one district would be looked upon as high-grade gasoline in another.

ACIDITY.

The test now recommended by the Bureau of Mines for determining acidity of gasoline is as follows: The residue left in the distilling flask after making a distillation is extracted with distilled water and tested with methyl orange indicator; reddening of the indicator shows that the gasoline contains acid which was present in the original sample, either free or in some sort of chemical combination. It has not been experimentally determined whether gasoline showing acidity according to this test has a particularly deleterious effect upon the metal parts of engines. It seems reasonable to suppose that it may have some undesirable effect, however, and inasmuch as this test is one which can be met by all refiners exercising reasonable care in preparing their products, it has been included in government specification. A study of the results of the Bureau's 1919 survey indicated that a majority of the samples were satisfactory according to this test.

UNSATURATION.

The test for unsaturation is one which the Bureau has never recommended in specifications as there is reason to believe that the types of unsaturated gasolines usually marketed are equal, if not superior in some ways, to the saturated types. The unsaturation test [6] is, however, interesting in showing the method by which gasoline was produced and is, therefore, worthy of brief discussion. The test employed by the Bureau simply involves agitating the gasoline with two volumes of ordinary concentrated sulphuric acid and noting what per cent. of the gasoline is dissolved. This test has been shown to cause a certain amount of polymerization of olefin or unsaturated hydrocarbons and on this account the percentage dissolved does not represent all of the olefines contained in the gasoline. As an empirical test, however, it has proven reasonably reliable and accordingly is of considerable value in the study of gasoline samples. The series of samples collected in 1917 varied in percentage of unsaturation from a fraction of one per cent. up to a maximum of six per cent. For

[6] Dean, E. W., and Hill, H. H., "Determination of Unsaturated Hydrocarbons in Gasoline"; Bureau of Mines Technical Paper No. 181, 1917, 25 pp.

the 1919 series the lower limit was the same but a common maximum was in the neighborhood of 12 per cent., showing that companies operating cracking processes have practically doubled the proportion of cracked gasoline turned out.

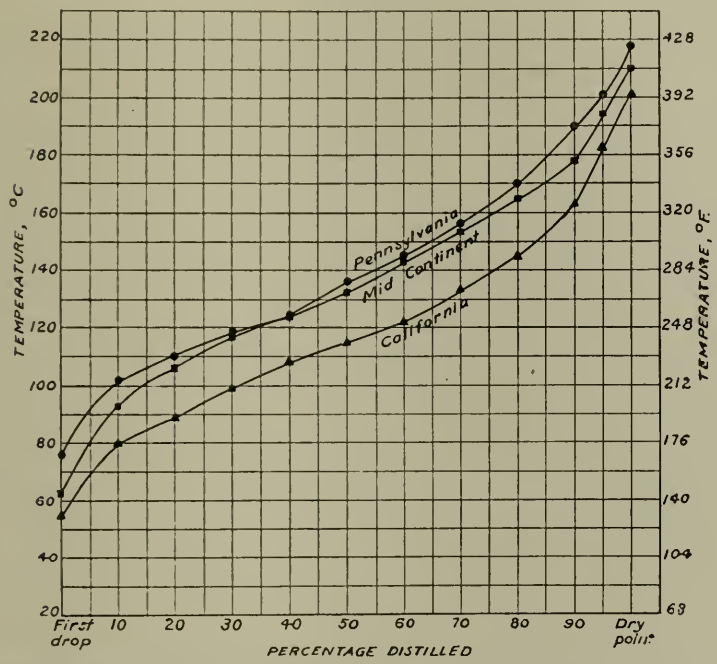
As regards the properties of cracked gasoline, a brief word may be in order. Cracked gasoline, even when carefully refined, has an odor which is more or less characteristic and which, to some at least, is slightly disagreeable. In addition, cracked gasoline is accused of the habit of polymerizing in shipment and storage with the depositation of gummy substances. Furthermore, cracked gasoline has been known to deposit gummy masses in the intake manifolds of engines and has also been accused of depositing carbon in cylinders. Some of these properties may be bad, although it is believed that in most cases the trouble is due to improperly refined cracked gasoline rather than to the simple presence of cracked constituents. In any event, however, some of the Bureau's experiments have indicated a notable point of superiority. When ordinary gasoline is used in a high compression motor there is likely to be a "knock" which is undesirable. Cracked gasoline has been found to be less subject to this tendency than is the more highly regarded straight refinery type. Frequent claims are made that cracked gasoline is superior to the straight run types when cars are run up steep grades or worked under heavy load, and the Bureau's experiments with the phenomenon of knocking have tended to substantiate these claims. In general, cracked gasoline is marketed in the form of blends which are not detected by the average user. It is believed, however, that even if the user were able to distinguish cracked gasoline, it would very likely be on account of its advantageous rather than its disadvantageous behavior.

GRAVITY.

Up to the last few years it was customary to rate gasoline on the basis of its Baumé gravity, and even to-day users are inclined to believe that a high Baumé gravity, which means a low specific gravity, is a desirable property. The gravity test under certain conditions does give indication of the distillation range of gasoline but in general furnishes highly unreliable information in this particular. It has already been pointed out that a mixture of kerosene and casing-head gasoline might have the same gravity

as a straight run gasoline. In addition it may be stated that the types of crude oil produced in different parts of the country have different physical and chemical properties and that for a given gravity there may be considerable difference in boiling range or *vice versa*. This fact is illustrated by the curves in Figure 15. The three samples represented have practically the same gravity,

FIG. 15.



Showing the distillation curves of gasoline of the same gravity obtained by the straight refinery process from Pennsylvania, Mid-Continent and California crude petroleum.

but have distillation ranges which are appreciably different. The uselessness of gravity figures in indicating quality of gasoline is further indicated by the fact that motor fuels now on the market may contain benzol and other coal tar derivatives which have abnormally low Baumé gravities.

GASOLINE SUBSTITUTES.

The subject of gasoline substitutes is one of particular interest, although definite information concerning it is decidedly limited. The first fact of importance to be recognized is that motor fuel is

essentially a source of energy and that the energy must come from somewhere. Wonderful statements regarding the discovery of new fuels appear periodically in the newspapers, these fuels generally being made by adding a small quantity of some secret compound to water. That these discoveries are one and all without particular value is proven by the fact that water is a substance which contains about as little free energy as anything one could select.

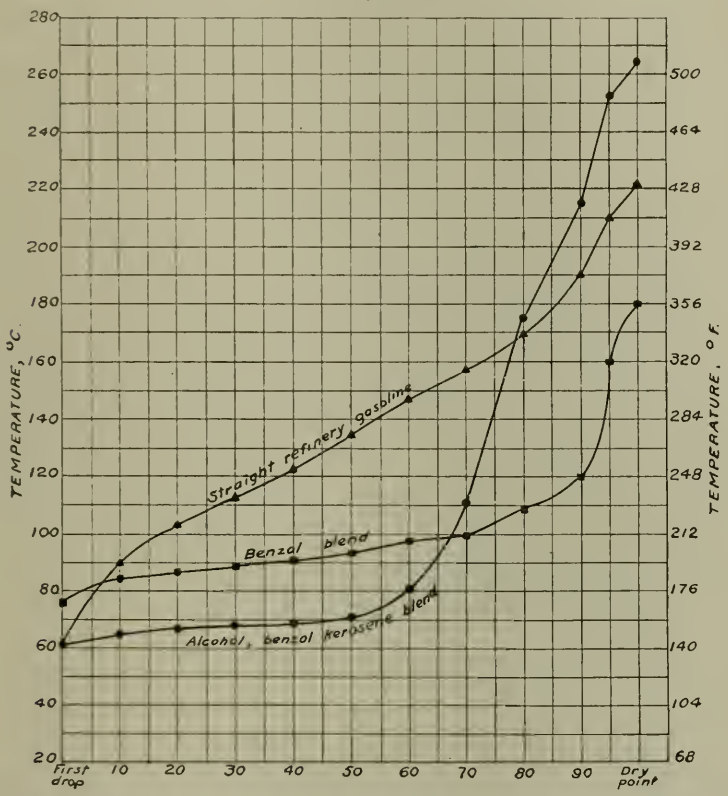
As regards the real possibilities of gasoline substitutes, it now seems probable that oil shale may in the future prove an important source. There are enormous deposits of oil shales in the United States and the extraction of liquid oil from these is undoubtedly feasible, although it has not yet been worked out on a commercial scale in this country. Oil shale probably will not assume any considerable importance as a source of motor fuel in the near future, but its potentiality as a resource gives a comfortable sense of assurance that the use of motor vehicles will not have to be discontinued when petroleum resources are exhausted.

Another type of fuel which offers unlimited possibilities for the future and which is already being developed to a certain degree is alcohol. The problems to be solved before this comes into general use are apparently the development of cheaper methods of production and the development of suitable types of engines. Efforts are at present being made to market a fuel containing alcohol and other components which may be used satisfactorily in present types of automotive engines. A sample of this fuel has been obtained by the Bureau in the retail market and has been subjected to laboratory examination. The distillation curve of this sample is shown in Figure 16. Its exact chemical composition was not determined but it was shown to contain both alcohol and benzol as well as a fair percentage of a product that might be classified either as a low-boiling kerosene or a high-boiling petroleum naphtha. The sample obtained by the Bureau was being sold at a price somewhat higher than that of motor gasoline. As regards its use, the Bureau has received reports from at least two reputable organizations, indicating that it was found at least as satisfactory as ordinary gasoline.

The type of gasoline substitute which is of most importance at the present time is the mixture of hydrocarbons obtained as a by-product in the coking of coal. These so-called coal tar distil-

lates, including benzol, toluol, xylol, etc., are hydrocarbons which are somewhat similar to the hydrocarbons found in petroleum, although of course there are well-recognized physical and chemical differences. During the war, coal tar distillates were largely used in the production of explosives and other munitions but since

FIG. 16.

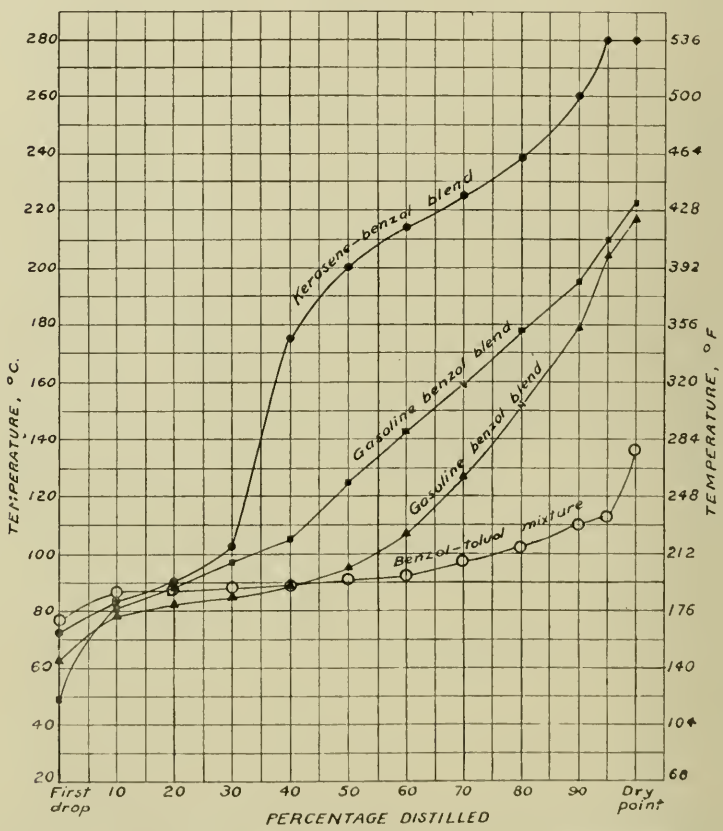


Showing distillation curves of three different types of motor fuel. (1) A blend of alcohol, benzol, and kerosene. (2) A blend containing benzol as principal constituent. (3) A straight refinery motor gasoline.

the termination of hostilities a considerable supply has been rendered available for motor fuel. Several companies have already undertaken to market benzol mixtures and in the course of its 1919 survey the Bureau secured a number of samples which were sold as gasoline substitutes containing benzol. The distillation curve of one of the samples is shown in Figure 16 and of some

of the other samples in Figure 17. The products are generally mixtures of coal tar distillates with petroleum naphtha. These products have been used under widely varying conditions and in some cases favorable results have been obtained, in others unfavorable results. Inquiries made by the Bureau have usually been

FIG. 17.



Showing distillation curves of four motor fuels containing coal-tar distillates.

answered by statements either that the substitutes were very satisfactory or very unsatisfactory, few of the users seeming to have found them about the same as petroleum gasoline.

The use of coal tar distillates as motor fuel does not, however, offer an ultimate solution of the motor fuel problem as the total production of these hydrocarbons is rather limited. In discussing

this subject in a paper prepared about two years ago the author had occasion to collect some statistics which are represented graphically in Fig. 18. This figure shows:

1. The nation's gasoline production in 1916.

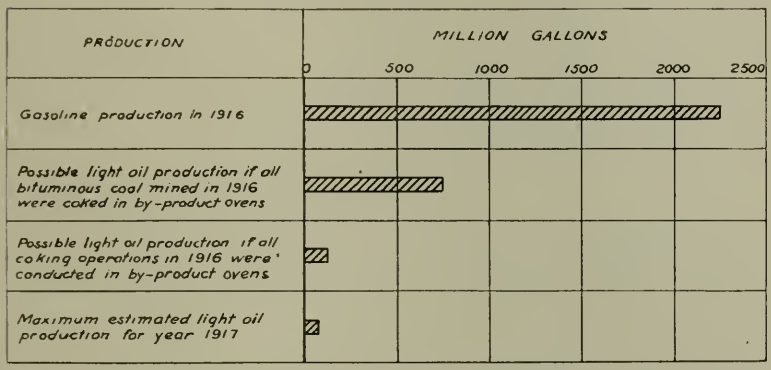
2. An estimate of the total light oil production if all the bituminous coal mined in the country were coked in by-product ovens.

3. An estimate of the production of light oil, if all coking ovens were of the by-product type.

4. An estimate of the actual light oil production for the year 1917.

The actual figure for hydrocarbons suitable for motor fuel is

FIG. 18.



Showing the relative magnitude of petroleum gasoline production as compared with possible resources of coal tar distillates.

even less than that for total light oil produced, and it appears, therefore, that as a motor fuel resource, coal tar distillates are of relatively small importance. It may, for instance, be stated that since 1916 the production of gasoline has practically doubled while the quantity of coal mined has increased only about 17 per cent. The real importance of coal tar distillates as motor fuel occurs in districts adjacent to by-product coking operations where a reasonable proportion of the local gasoline supply may be filled by coal tar products.

Benzol and other coal tar distillates have certain disadvantages when compared with petroleum gasoline but have other very marked advantages; particularly in freedom from tendency to knock. An additional advantage lies in the fact that they have

a considerably higher calorific value per unit volume, and as this is the basis on which the user buys, he gets more for his money than he would from petroleum gasoline. It is believed that coal tar distillates, if properly used, are very satisfactory motor fuels and that there should be little difficulty in finding a market for the entire supply.

The Bureau's general feeling with regard to substitutes for gasoline is that they should receive all possible encouragement if produced and marketed in an intelligent and scientific manner. The nation certainly needs to increase its motor fuel resources and no step in this direction should be hindered. It should be recognized, however, that petroleum gasoline is a type of fuel for which present equipment has been designed and for which it is eminently satisfactory. It is believed, therefore, that when striking claims are made for the superiority of any gasoline substitute, these should not be taken too seriously. The substitute fuel should be given a fair trial but the user should be satisfied if it is as good as gasoline and should not expect it to be notably superior.

New Methods of Constructing Buildings in France. (*La Nature,* December 27, 1919.)—The shortage of workers and the pressing need of buildings in the Departments devastated by the Huns has led to new devices in which the saving of time and the reduction of hand labor are prominent. In the process of M. Ch. H. Besnard, an architect of the Government, elements of reinforced concrete are moulded in the factory under favorable conditions of temperature and humidity, where workmen are on the ground and not in mid-air, and where inspection and tests can be carried out with satisfaction. In erection a skeleton, consisting of (*a*) posts, carrying at the upper end very stout metal gutters, and (*b*) horizontal girders connecting the posts, is put up. The gutters, themselves, serve as lengthwise girders. From the peak of the roof descend the two sloping sides of glass or of tile, and both rest upon the inner edges of the gutters on the two sides of the structure. Outside of the actual elevation of the members and of their fixing in place, but little work need be done at the site of the structure. The roof has only three joints.

The same process is applied to dwelling houses as well as to factories, and in a characteristically French manner the esthetic features of the structures are cared for.

It is reported that a saving of more than 90 per cent. in the number of workers at the building itself is thus made—no inconsiderable matter in view of the 450,000 ruined buildings in France.

G. F. S.

A NEW NON-INTERMITTENT SENSITOMETER.*

BY

LOYD A. JONES

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THE first step in the testing of photographic plates, films, and papers by the sensitometric method involves the exposure of the material in some definite precisely determined manner. This is accomplished by use of an instrument known as a "sensitometer," which subjects various areas of the material to be examined to a series of exposures varying in value over the necessary range and in accordance with some definitely known predetermined ratio. Since the density of the developed areas over a considerable proportion of the scale of the material is directly proportional to the logarithm of the exposure, and, since it is usually desirable in producing a graphical representation of the characteristics of the material to plot density against the logarithm of the exposure, a series of exposures increasing according to some logarithmic function is usually chosen, thus producing an even distribution of determined points along the exposure axis. The exposure scales in most common use are those in which the exposures increase from step to step by consecutive powers of 2, $\sqrt{2}$ or $\sqrt[3]{2}$, the particular scale used being that one which is best suited to the scale of the material being tested and to the requirements of precision necessary in the problem being considered.

The response of a photographic material to the stimulating exposure is a function not only of the intensity (I) of that stimulus, but also of the duration of time (T) through which the stimulus acts. Exposure, therefore, consists of two factors, time and intensity, and hence its value may be varied by a change in either the time or intensity factor. The desired variation in the time factor may be accomplished by either of two general methods, the continuous or intermittent. In case of the former the exposing radiation is allowed to act continuously from the instant of starting until the desired exposure has been obtained, while in the latter the exposure is broken up into a series of flashes varying

* Communicated by Dr. C. E. K. Mees. Communication No. 64 from the Research Laboratory of the Eastman Kodak Company.

in duration for the various areas being exposed. There are in general, therefore, three distinct ways in which a photographic plate may be exposed for sensitometric purposes, and sensitometers may conveniently be divided into three classes according to the way in which the required variation of exposure is obtained:

CLASS A: I variable, T constant (Intensity Scale Instrument).
CLASS B: I constant, T variable and continuous (Non-intermittent Time Scale Instruments).
CLASS C: I constant, T variable and intermittent (Intermittent Time Scale Instruments).

Sensitometers producing graded exposures in all three of the ways mentioned above have been used by various workers in the field of photographic research.

The chief examples of Class A are the tube sensitometers and tablet sensitometers. The former consist of a series of tubes or cells of equal lengths at one end of which is placed the photographic plate, the other ends of the various tubes being closed by opaque plates containing apertures of variable areas. If these apertures are properly illuminated, the intensity of the light acting on the photographic plate at the other end of the tubes will be proportional to the areas of the apertures. In order to obtain high precision with this type, extremely good machine work is necessary, and great care must be exercised in obtaining proper illumination of the apertures. Difficulty also arises in obtaining a long scale of exposures and at the same time placing the exposed areas close together on the plate, this being highly desirable in order to minimize as much as possible the errors arising from the inequalities of coating. Sensitometers of this type have been used by Spurge,[1] Vogel,[2] Luther[3] and others.

Tablet sensitometers are made by producing on a transparent support, such as glass or film, a series of deposits varying in density according to the desired scale of exposures. These densities may be produced by use of pigmented or neutral dyed gelatine or by a photographic deposit of silver grains developed in a non-staining developer. The plate to be tested is printed in contact with the tablet and the densities of the various tablet areas, having been previously measured, the intensity of the light acting on the various areas of exposed plate can be determined. The chief difficulties in the preparation of such tablets lie in the exact measurement of the various densities, in obtaining and reproduc-

ing precisely the densities desired and in obtaining media that are photographically non-selective in regard to spectral absorption. The best known examples of this type are the Warnerke [4] and Chapman-Jones [5] tablets.

Sensitometers of Class B have been but little used. One form proposed by Cowan [6] consists of a plate which is allowed to fall, under the action of gravity, between the light source and the material to be tested. In this plate is cut a series of slots of different lengths, allowing the light to act for various intervals of time upon the areas of sensitive surface behind the several slots. The chief objection to this type is the necessity of applying a correction to compensate for the variable velocity of fall due to gravitational acceleration. Another form proposed by General Sebert [7] is much more satisfactory but does not seem to have been used very extensively. This consists of a plate-holder, carrying the sensitive material to be exposed, driven at a constant velocity past a metal plate, in which are cut slots of different lengths. The constant velocity is obtained by means of a clock-work controlled by a pendulum.

Class C includes instruments of the sector wheel type. These consist of an opaque disk in which are cut slots of various angular dimensions, mounted on a shaft, and driven at a fairly high angular velocity. The material to be exposed is placed behind this rotating disk and various areas receive exposures which are directly proportional to the angular dimensions of the slots. This instrument has been very extensively used in photographic research and is the most common and best known form of sensitometer. This form was proposed as early as 1840 by Claudet, and again in 1889 by Bolton.[8]

Various workers have used instruments of this type differing slightly in detail; for instance, Hurter and Driffield [9] adopted one, employing a disk having nine steps, increasing in angular dimensions by consecutive powers of 2, thus giving exposures doubling in value from step to step. Scheiner [10] adopted a disk in which the ratio of adjacent slots was 1 : 1.27, thus giving the determined points very close together on the exposure axis and for a given number of steps covering a relatively small range of the scale of the material. An instrument of this type was constructed in this laboratory having a disk cut so as to give exposures, increased by consecutive powers of $\sqrt[3]{2}$ for use in the testing of

photographic printing papers which have a scale much less than that of plates, or for the very precise determination of a portion of a plate characteristic, the increased precision obtained being due to the fact that three times as many points are determined as with the instrument giving exposures increasing by powers of 2.

A very complete description of the sector wheel sensitometer and a discussion of the precision obtainable in the cutting of the disk has been published by Sheppard and Mees.[11]

The chief objection to the sector wheel instruments is due to the fact that a photographic surface does not in general integrate an intermittent exposure. The effect produced, generally referred to as the intermittency effect, has been investigated by Abney,[12] Vogel,[13] Schwarzschild,[14] Howe,[15] and others. Sheppard and Mees have found that under certain conditions, at least, this failure of the plate to integrate an intermittent exposure is not appreciable.

It has been considered by most workers in this field that such instruments, when operated with the speed of rotation of the disk between certain limits, would give at least correct relative values of speed for various materials and practically all speed determinations have in the past been made with this type of sensitometer.

In the course of the sensitometric work carried on in this laboratory, it was noticed that certain discrepancies between the relative speed values determined by these instruments and those measured by exposure in the camera were occurring. These were especially notable in the case of the relative values for materials differing widely in speed, such as, for instance, negative and positive emulsions. In the determination of the speed of the slow material with the sector wheel instrument it was found necessary to multiply the standard exposure time by some factor in order to obtain a number of points sufficient for the satisfactory determination of the shape and position of the characteristic curve. Then, in order to obtain the correct relative speed value, the speed read from the curve thus established was divided by the factor used in increasing the exposure time. It was also noted that speed values obtained by using increased times of exposure were not proportional to such increases of time, even on the same material.[16]

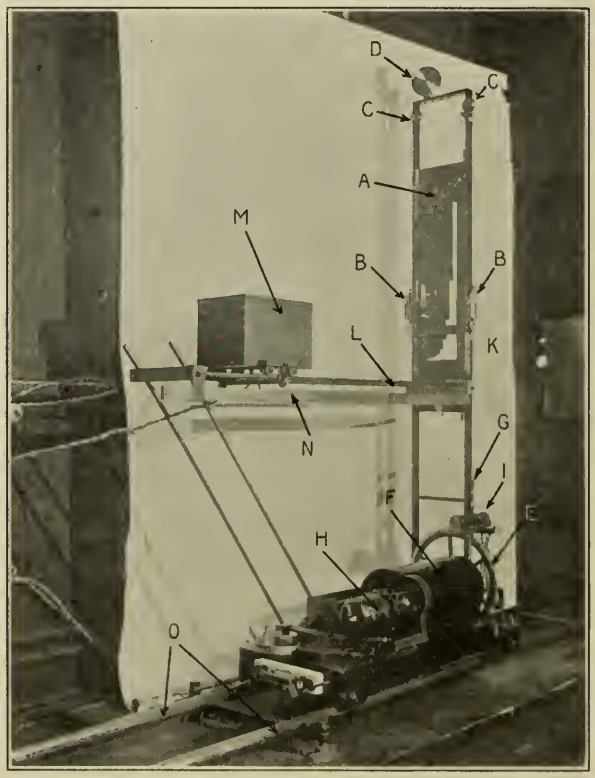
On account of the existence of the discrepancies mentioned above, it was decided to replace the rotating sector sensitometers, in which the exposure is intermittent, by new instruments of Class B, giving continuous exposures with the intensity constant and time variable. Several types were developed, and in the following pages only brief mention will be made of these and the larger part of the space devoted to a detailed description of the form finally adopted, together with data showing the difference between the performance of this and the intermittent machines.

The instruments to be described may be divided into two general types: (1) Those using a thin metal plate in which are cut slots of various lengths, those lengths being proportional to the exposures which it is desired to impress on the sensitive material. Such plates are then moved across the surface of the material to be exposed at a velocity which must be maintained at a precisely uniform value from the instant at which the exposure starts until it is terminated. (2) In this class of instruments the slotted shutter plate, moving at a uniform velocity, is replaced by a shutter plate which is caused to move in a discontinuous manner across the surface of the sensitive material. This motion is produced by the application of a series of impulses, each one of which causes the shutter plate to move a fixed distance at an extremely high velocity, the time intervals between the application of successive impulses being so adjusted that a series of exposures increasing by successive powers of either 2, $\sqrt{2}$ or $\sqrt[3]{2}$ as may be desired, is impressed upon the sensitive material. The distance through which the shutter is moved depends upon the size of the area required for measurement. The velocity of movement is made as high as possible in order that all points of a given area shall receive equal exposures. A consideration of the principles involved in these two types of instrument shows that in the case of the former type (1) the precision obtainable depends upon the accuracy with which the various slots in the shutter plate can be cut and upon the uniformity of the velocity with which that plate can be moved throughout the entire exposure period; while in the latter case, (2), the entire burden of securing precision is thrown upon the mechanism which determines the time intervals between the successive impulses applied to the shutter plate.

The first instrument constructed, Fig. 1, was of Type 1 (Class

B). An aluminum plate, *A*, 15 cm. wide by 60 cm. long, is mounted so as to move up and down between vertical ways. The weight of this plate is balanced by two counter poise weights, *B*, *B*, carried at the ends of silk cords attached to the upper end of the plate and running over small pulleys, *C*, *C*, located at the

FIG. 1.



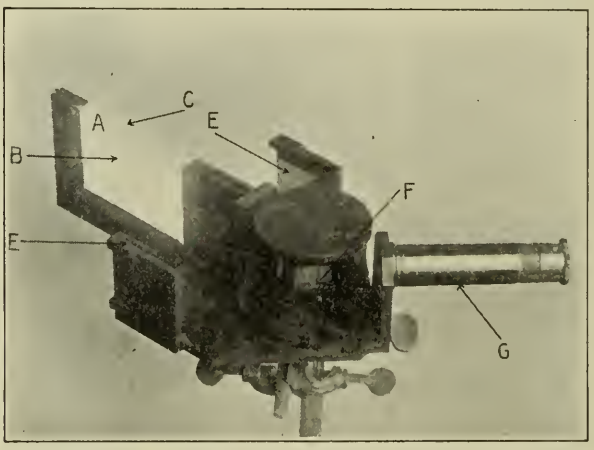
top of the ways, one on each side. The plate is moved up and down in the ways by means of a silk cord attached to the top and bottom of the plate and running over the grooved pulley wheels, *D* and *E*, of which the larger one, *E*, is the driving member, *D* being an idler. Power is applied to *E* through a train of gears, not shown in the photograph, connected with the shaft of the chronograph drum *F*. The train of gears is so arranged that by moving the lever, *G*, into the proper position, the plate may be made to move either up or down, and the gear ratios are so

adjusted that the linear velocity of the plate when moving down is sixteen times as great as when it is moving in the upward direction. A Leeds and Northrup constant speed-governed motor furnishes the power for operating the mechanism, and is connected to the shaft of the chronograph drum by means of a worm and worm-wheel. Four interchangeable worm-wheels are provided, having different numbers of teeth, so that angular velocities of 1, 2, 4 and 8 units may be imparted to the drum, thus making it possible to vary the exposure time over a considerable range. In order to eliminate the possibility of injury to the mechanism, due to the failure of the operator to shut off power, or to throw the lever, *G*, into its neutral position when the plate has reached the end of its travel, electric contacts are placed at the upper and lower ends of the ways so that when the plate reaches either of its extreme positions, a low voltage circuit is closed, which energizes the solenoid *I*, which in turn opens the 110-volt circuit supplying power to the driving motor *H*. The photographic plate to be exposed is carried in a plate holder, which slides into position behind the shutter plate at *K*. Two interchangeable shutter plates are provided, in one of which the length of the opening increases by powers of 2 and in the other by powers of $\sqrt{2}$. The nine steps are each 1 cm. wide and their lengths are precisely limited by means of adjustable steel edges attached to the aluminum plate by screws. In case of the very short steps the length is adjusted to the desired value by use of a micrometer microscope. In the face of the plate holder are two openings, each 1.5 cm. wide by 9 cm. long, and separated by a distance of 1 cm., each opening being provided with a dark slide. In using the shutter plate in which the openings vary by powers of $\sqrt{2}$, the dark slide covering the upper opening in the plate holder is withdrawn, while the shutter plate travels up. When the shutter plate has completed its upward motion this dark slide is pushed in and the one covering the lower opening is withdrawn, while the shutter plate moves down at sixteen times its upward velocity. In this way a sensitometer strip consisting of two nine-step portions is obtained, having seventeen steps with exposures increasing by powers of $\sqrt{2}$, there being one step on each, having equal exposures for the purpose of checking. In case the shutter plate having the steps increasing by powers of 2 is used, a series of nine exposures varying from 1 to 256 is obtained by allowing

the shutter plate to travel in one direction only, and as this range is sufficient for most cases, it is not necessary to make use of the double motion of the shutter. Both dark slides may therefore be withdrawn and the two strips exposed simultaneously.

In some instances it becomes necessary to measure the intensity of illumination acting on the photographic plate and to provide for such cases a photometric attachment is provided. A pair of ½-inch steel rods, *LL*, are mounted in a horizontal position, as shown. Moving on this track is a light tight box *M*, in which is mounted a small standard incandescent lamp. An aperture in

FIG. 2.



the end of the box permits the light from this lamp to fall upon the back of the plate holder *K*. Now, in order to measure the intensity of the illumination incident upon the plane occupied by the photographic plate during exposure, the plate holder is removed and in its place is inserted the special photometer head shown in Fig. 2. The photometer screen *A*, consisting of a block of magnesium carbonate the opposite surfaces, *C* and *D*, of which are carefully cleaned by scraping down with a steel straight edge so as to be of equal reflecting powers, is mounted so that when the attachment is in position the surface *C* lies in the plane occupied by the photographic plate when it is in position for exposure. Two mirrors, *EE*, a photometer cube, *F*, and eye-piece, *G*, constistute the essential parts of this attachment which is very similar to the ordinary Lummer-Brodhun photometer head. When this

is in position the surface *C* is illuminated by the light used for exposing the photographic plate while *B* is illuminated by light from the standard lamp in *M*, Fig. 1. A photometric match is made by running *M* back and forth on the track *LL*, and the distance of the lamp from *B* is read off on scale *N*, Fig. 1. The candle-power of the lamp being known, the illumination on *B*, Fig. 2, and hence on *C* can be computed. In case the intensity of the exposing light is extremely variable and it is desired to read the illumination on the photographic plate during exposure, the magnesium carbonate block *B* can be removed from its position and in its place can be inserted a holder containing the photographic plate to be exposed. The plane of the plate to be exposed occupies the same plane as surface *C*. In order that the two sides of the photometric screen shall be of equal reflecting power, a second photographic plate is placed so that its face occupies the plane of surface *B*. In such a case the room in which work is being done must be darkened and illuminated only by the proper safelight. By the use of such a photometric screen, the faces of which are composed of photographic plates, the intensity readings may be made while exposure is taking place. The entire sensitometer is mounted on a heavy metal base which can be moved to any desired position on the track *OO*. This instrument gave very satisfactory results, although considerable difficulty was experienced in obtaining a sufficiently uniform velocity of the shutter plate, and in keeping the various parts of the mechanism in good adjustment. These disadvantages, together with the fact that considerable skill and experience is required on the part of the operator, makes the instrument unsuitable for routine work.

In an effort to devise an instrument more completely automatic in action, requiring less attention on the part of the operator, and at the same time giving precisely timed exposures, attention was turned to the second type (2), of Class B, in which a series of separate impulses are applied to the shutter plate.

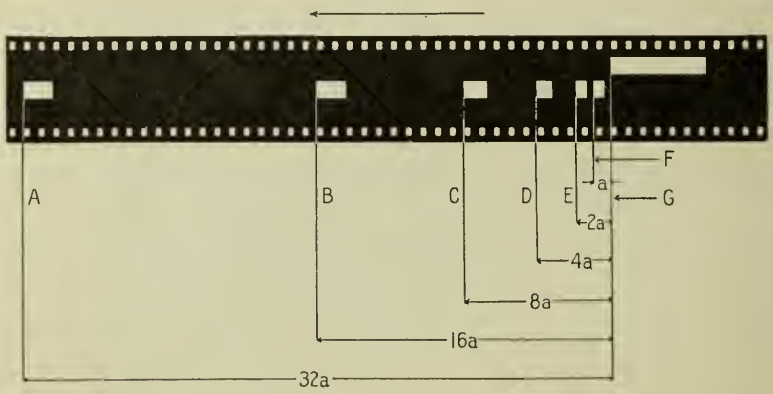
For the purpose of description such a sensitometer may be divided into two parts: (1) the timing device which closes the electric circuit at the proper instants of time, thus furnishing the desired series of impulses; and (2) the exposing machine, consisting of the light source of constant intensity which may be covered and uncovered at the proper instant by an impulse furnished by the timing device, a sliding shutter plate so constructed

as to be operable by a series of impulses from the timing device, a plate holder carrying the photographic plates to be exposed, a plate holder slide for holding the plates in position behind the sliding shutter, and the necessary control keys for starting and stopping the timing mechanism. The elements of the exposing machine are all mounted together, forming a complete unit which can be used in an undarkened room and at any desired position in the building irrespective of the location of the timing device.

THE TIMING MECHANISM.

As previously stated, the burden of obtaining precision in this type of sensitometer is thrown upon the mechanism which deter-

FIG. 3.

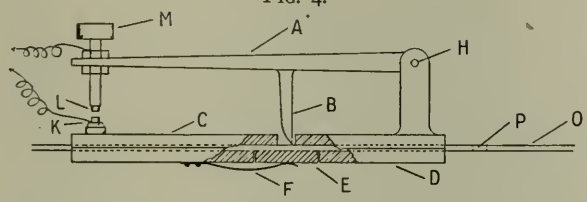


mines the time intervals between successive impulses. After careful consideration and preliminary trials, it was decided to adopt a perforated tape as a means of producing the correctly timed series of impulses. This tape is made by punching holes *A*, *B*, *C*, etc., spaced at the proper intervals, in a strip of motion-picture film as shown in Fig. 3. This film is then drawn through a contact maker at a constant linear velocity by means of a mechanism driven by a constant speed-governed motor. As each hole passes a certain point in the contact maker a contact is made which operates a relay which in turn energizes a solenoid, the plunger of which is so arranged as to move the shutter plate one step in the desired direction. In the first model the film itself was allowed to run directly between the two points of the contact maker, thus allowing them to come together only when one of the holes came

into position. This required that one of the points press continually on one surface of the film and it was found that this contact point soon became fouled, due to the collection of dust and particles of the film itself, so that the making of a good electrical contact was very uncertain. A contact maker, such as is shown in Fig. 4, was then devised, and has proven very satisfactory. The figure is a partial cross section showing the film *O* in position between the two metal plates *C* and *D*, which are separated by a distance equal to about twice the thickness of the film. This distance is necessary in order that a splice in the film may pass easily between the plates. The arm *A*, pivoted at one end on the point *H*, carries at the other end a screw *M*, with a platinum contact point *L*, at its lower extremity. The other contact point *K* is mounted on plate *C*, as shown.

At a distance from *H*, equal to one-sixth of the total length

Fig. 4.



of the arm *A*, is a steel lug *B* rigidly attached to *A* and projecting through an opening in plate *C*. The lower extremity of this lug rests upon the upper surface of the film *O*, and supports the arm *A* at such a height that *L* and *K* are separated by about 1 mm. When a hole in the film comes into position under lug *B* its edge moves down by the thickness of the film .2 mm., allowing *L* to move down by six times that distance, thus making a contact between *L* and *K* which completes the relay circuit. The hardened steel plate, highly polished on the upper surface, is fitted into an opening in plate *D*, as shown, and is pressed upward against the lower face of the film by the spring *F*, thus keeping the film pressed firmly against the lower face of plate *C* at all times.

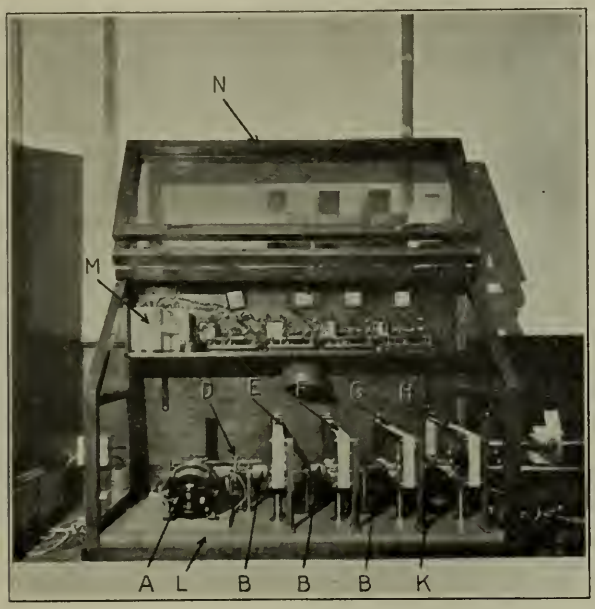
The film containing the perforation is pulled through this contact maker by means of a film sprocket, on the circumference of which are rows of teeth engaging the perforations along the edges of the film. This sprocket is driven at a constant angular velocity by means of a governed motor so that the number of perforations

passing a given point in a fixed time will be constant. Since a long strip of film may change its length slightly with age or with variation in conditions of temperature and humidity, the spacing of the operating openings (*A, B, C,* etc., Fig. 3) is determined in terms of the number of edge perforations rather than by actual linear measurement. This procedure eliminates any error of timing that might result from a linear expansion or contraction of the film due to any of the various causes of change of length. A special punching device is used for spacing the operation openings. This consists of a film sprocket to the axis of which is attached a large graduated circle with vernier scale. As this sprocket is turned the film is pulled through the punching die and the distance between successive openings can be read in terms of the number of edge perforations to within .01 of an edge perforation interval.

Since it was desirable to operate several exposing machines at the same time, a central station (Fig. 5), consisting of a multiple timing device was constructed, thus utilizing one governed motor for driving several contact makers. The governed motor *A* is connected through a worm and worm wheel and a pair of spur gears of a ratio of 1 to 1 to a long counter-shaft on which are mounted three film sprockets, *B, B, B,* running free on the counter-shaft. Near each sprocket and fixed to the counter-shaft is mounted an iron-clad magnetic clutch, the soft iron armature of which is attached to the film sprocket. When any one of these magnetic clutches are energized the corresponding armature is seized, thus causing the attached film sprocket to rotate at the same angular velocity as the counter-shaft. The speed of the motor and gear ratios are so adjusted that the film bands *E, F* and *G* are drawn through the contact makers at the rate of four edge perforations per second. The fourth clutch, *K,* is mounted on a separate counter-shaft connected to the main counter-shaft by interchangeable spur gears of such ratios that velocities of 1, 2, 4 8 or 16 edge perforations per second may be imparted to the film band *H* at the will of the operator, thus permitting the total time of exposure to be varied over wide limits. In case further range of variation is desired, the pair of spur gears *D* may be changed, giving either four times, or one-fourth of the standard rate of rotation, to the main counter-shaft. The motor, counter-shafts, and contact makers are mounted on a heavy cast-iron base *L,* forming the bottom of the oak cabinet which houses the entire

central station. On a shelf above are mounted four relays and the eight-volt dry-cell battery *M* furnishing the electromotive force for the primary relay circuits. In the rear of the cabinet are the four film containers *R*, containing the film of the various timing tapes. In these containers the film is looped back and forth over rollers mounted at the top and bottom of the boxes, each container having a capacity of about seventy feet of film. The film records after being punched are made into continuous

Fig. 5.



bands by splicing the ends together. They are then placed in the containers which are shifted into position, a loop of the film being pulled out, threaded through the contact makers and over the guide rollers as shown in Fig. 5. A spring tension is provided inside each container so that all slack is automatically taken up, causing the film to run uniformly, thus making more certain satisfactory operation of the contact makers. By lowering the hinged doors *N*, all of the mechanism is inclosed in a dust-proof case.

As was stated previously, it is necessary to shut off the exposing light at the proper instant. This is accomplished by means

of a pair of auxiliary contacts on the contact maker, slightly offset from the central line of openings. A single opening *G*, Fig. 3, in the film band is punched at the proper distance from the last of the main series of openings and offset so as to come into position over the auxiliary contacts. This pair of contacts is arranged so that the film band when in position in the contact maker depresses the end of the pivoted lever, the other end of which presses against the contacts holding them together. When the offset opening *G* comes into position over the end of the lever the pressure is released, the contact part thus opening the electric circuit. Through this circuit flows the current which energizes the magnetic clutch, causing the film sprocket to rotate and in series with the clutch is a solenoid used for cutting off the exposing light. In case an acetylene burner is used as a source, this solenoid when energized holds open a shutter placed between the burner and the plate to be exposed. The breaking of this circuit by the coming into position of the opening *G* de-energizes the solenoid, allowing the shutter to close instantly under the action of a coiled spring. At the same time the clutch is released, causing the film band to stop in position for the next series of exposures. The acting edge of lug *B*, Fig. 4, is precisely aligned with that of the lever operating the auxiliary contacts, so that in punching the film record the position of the leading edge of opening *G*, relative to that of *F* (the last of the central series) can be accurately determined by means of the punching die used for spacing the central series of holes. This is accomplished by constructing the punching die so that the punch can be offset in a direction exactly perpendicular to the linear axis of the film strip and by an amount such as to bring the offset hole over the auxiliary contact of the contact maker. Fig. 3 is a contact print from a portion of one of the film bands actually used. The direction in which it travels through the contact maker is indicated by the arrow. The dimension lines are drawn to the leading edge of each opening which are so spaced as to give a series of exposures, increasing by consecutive powers of two. This record, run at four perforations per second, gives exposures of .312, .625, 1.25, 2.50, 5.00 and 10.0 seconds' duration.

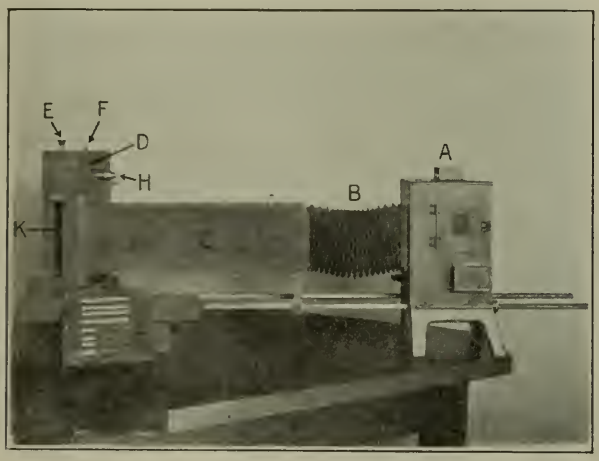
It is evident that any desired series of exposures may be given by proper spacing of the openings in the film bands. This flexibility constitutes one of the chief advantages of this type of timing device.

THE EXPOSING MACHINE.

In Fig. 6 is shown one of the complete exposing machines, *A* being the lamp-house inclosing the standard acetylene burner, and the shutter which terminates the exposure, together with its operation solenoid. The extension bellows *B*, providing for the adjustment of the lamp distance, connects the lamp-house with the extension box *C*, which is fitted with filter holders, carrying the acetylene to daylight filter, or any other filter or filters that it may be necessary to use.

The housing, *D*, incloses the shutter plate, the mechanism

Fig. 6.

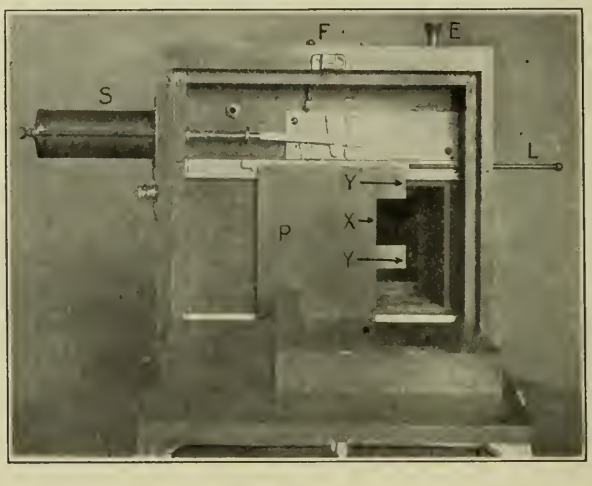


for its operation and the plate holder slide. *H* is a small pilot light in series with the magnetic clutch of the timing mechanism and the solenoid operating the lamp-house shutter serving when lighted as an indication that the mechanism is operating. The starting key *E* is a tapping key of the ordinary type wired in parallel with the auxiliary contact of the timing mechanism. When this key is depressed the magnetic clutch is energized, pulling the film forward, thus displacing hole *G*, Fig. 3, and closing the auxiliary contact. Key *E* can then be released without opening the clutch circuit, the clutch remaining energized until hole *G* again comes into position under the auxiliary contact. The member *F* releases the mechanism so that the shutter plate may be pulled back to its initial position for starting a series of

exposures. *K* is the plate holder slide and *L* the plate holder used in this particular instrument. In Fig. 7 is shown an end view of exposing machine opened so as to disclose the shutter plate and the operating mechanism above. The solenoid *S*, being energized by the timing device, furnishes the power for moving the shutter plate.

The shutter plate moves in the horizontal direction and through a distance of 1 cm. at each impulse. The openings in the front of the plate holder are 10 cm. long by 1 cm. wide, giving an exposed area of these dimensions on the photographic plate,

FIG. 7.



each strip consisting of ten steps, each 1 cm. square. It will be noted that the shutter plate used in this machine has two projecting portions *YY*, on the right-hand edge. These are 3 cm. long and are so spaced relative to the openings in the plate holder that the upper opening of each group of four is covered by the projecting portions. At the start of the exposing operation the edge *X* is coincident with the edges of the opening in the plate holder, thus completely protecting the photographic plate from the action of the exposing light after the dark slides of the plate holder are pulled out. Exposure of three strips of each group of four begins with the first impulse while the other two strips are protected by the projections *YY*, until the application of the fourth impulse. This arrangement is provided in order that one strip of

each group of four shall receive only one-eighth as much exposure as the other three.

A tablet consisting of strips of the standard tricolor filters *A* (red), *B* (green), *C* (blue), and Dummy, is placed inside the plate holder, the dummy filter being over the opening lying behind the projections on the shutter plate. This instrument is used for the determination of the exposure factors of color sensitive materials for the tricolor taking filters and is known as the tricolor sensitometer. In the instruments used for ordinary speed testing, a shutter plate with a straight edge is used, the projections being unnecessary when all the strips being exposed are to receive equal exposures.

In Fig. 8 is shown the wiring diagram of the complete apparatus, the circuits of the exposing machine being shown to the right of the figure and those of the central station timing mechanism at the left. In order to simplify the description of this figure the meaning of each symbol will be given in tabular form as follows:

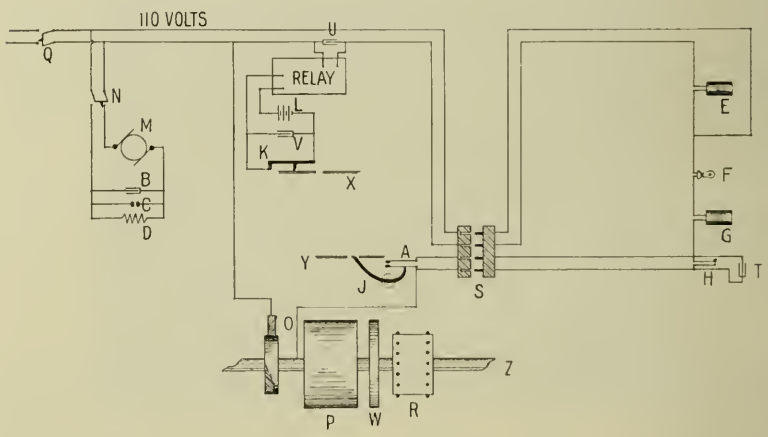
Q = Main line switch.
N = Motor switch.
M = Constant speed governed motor.
B = Condenser for suppression of spark on gap *C*.
C = Governor contacts.
D = Shunted resistance coil.
L = Eight volt battery on relay circuit.
K = Main contact of contact maker.
V = Condenser to choke spark at *K*.
U = Condenser to choke spark on relay contact.
X = Portion of film band.
Y = Portion of film band.
A = Auxiliary contact.
J = Lever operating auxiliary contact.
P = Magnetic clutch.
W = Clutch armature.
R = Film sprocket.
Z = Countershaft.
O = Slip ring and brush carrying current to clutch winding.
E = Solenoid operating shutter plate.
F = Pilot lamp.
G = Solenoid operating lamp-house shutter.
H = Starting contact.
T = Condenser for choking spark at *H* and *A*.
S = Four point plug connector.

In Fig. 8 are shown the circuits for a single instrument and these circuits are duplicated for each additional unit. One part of the four plug connectors, *S*, is mounted on the central station cabinet, the other being wired to the end of the cable leading to the exposing machine. The connections are made interchangeable so that any one of the exposing machines may be plugged in on any

one of the four timing mechanisms in the central station, making a very flexible and convenient arrangement.

In Fig. 9 is shown a special sensitometer built on the same principle as the ones just described. This is built to be used in a dark room and is for convenience provided with its own governed motor *A*, and contact maker *C*, although it may also, if desired, be operated from the central station, shown in Fig. 5. The exposing machine is at *B* and the light source in the housing *D*. In Fig. 10 is shown a detail of the shutter plate, the mechanism for its operation and the holder for the sensitive material to be exposed. This was constructed primarily for the testing of

FIG. 8.



photographic printing papers and takes an 8 x 10 sheet of the material. The paper is placed in position in front of the board *E*, which is then turned into a vertical position and locked, holding the sheet of paper in place during exposure. In case it is not desired to expose the entire surface, a suitable template with narrow vertical openings, or with a series of small circular apertures, may be placed in the holder before inserting the sensitive material. In this way sensitometric exposures may be impressed near the edges of a sheet while the centre is reserved for printing from a negative, thus giving, when developed, the sensitometric characteristic and a picture upon the same sheet of sensitive material and also assuring identical treatment in the development of the two. The mechanism is so arranged as to give twenty-five expos-

Fig. 9.

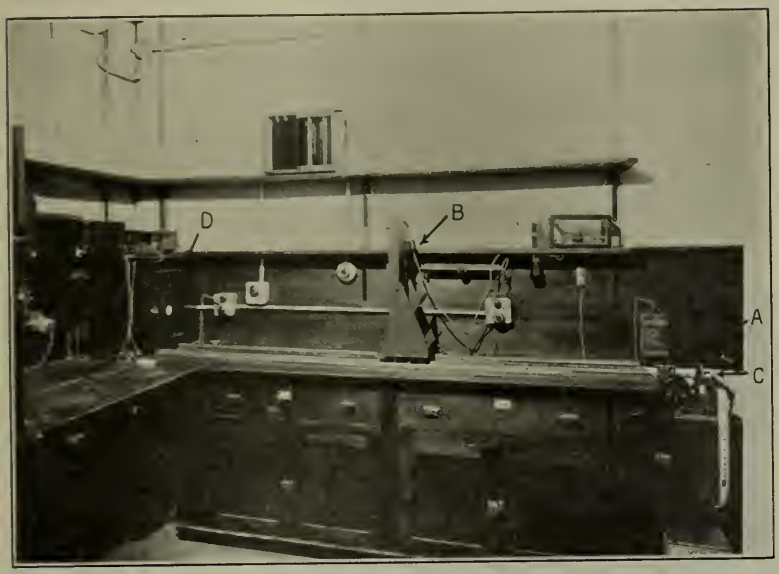
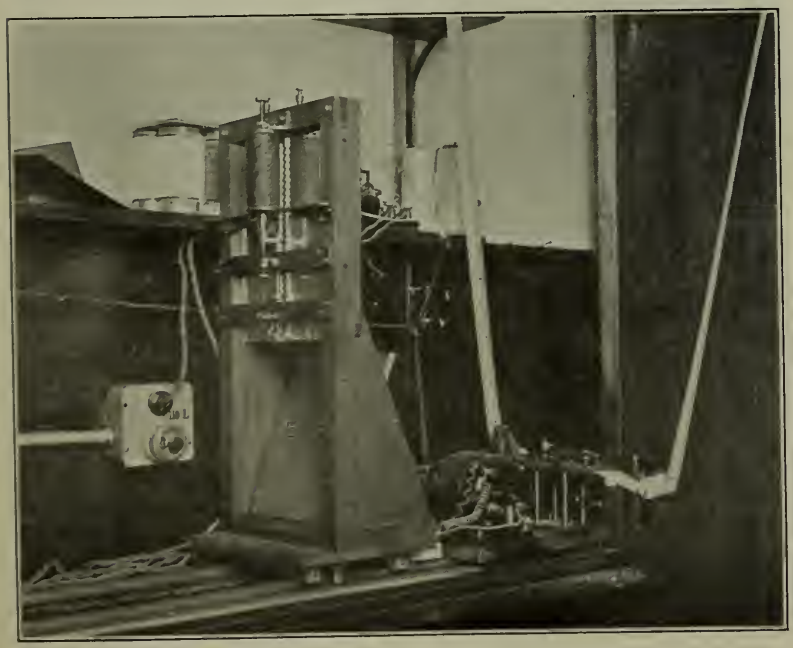
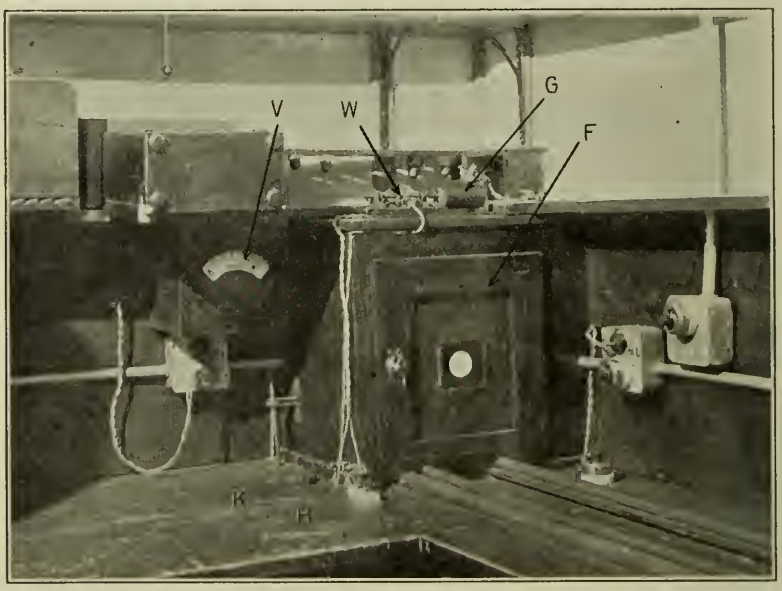


Fig. 10.



ure steps and since papers as a rule have relatively short scales, film records giving a series of exposures, increasing by powers of $\sqrt{2}$ or $\sqrt{3}$, are usually used in order to provide a sufficient number of points for the precise determination of the shape of the characteristic curve. Photographic plates, 8 x 10 inches, may be exposed in this machine with equal facility. A detail view of the lamp-house is shown in Fig. 11. An electric incandescent lamp inside the housing illuminates a sheet of opal glass (10 x 12

FIG. 11.

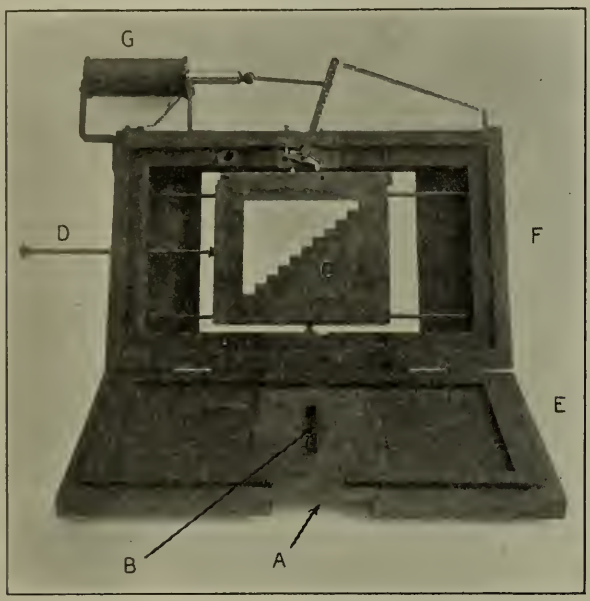


inches), set in front of the lamp-house behind the door frame *F*. A set of metal plates of the same dimension as the opal glass is provided in which are cut circular apertures of various dimensions, the area of the aperture increasing from plate to plate by powers of 2. Any one of these may be held in position over the opal glass thus limiting the effective area of glass used as a source. In order to still further vary the intensity of illumination incident on the material being exposed, the distance between the opal glass and the exposing machine may be varied and read from a scale attached to the track on which the exposing machine moves. The solenoid *G* (equivalent in function to *G*, Fig. 88) terminates the

exposure at the proper instant, not by operation of a shutter, as in the case of instruments using the acetylene as a light source, but by opening the switch *W*, through which current flows to the lamp in the lamp-house and to the operating motor. The starting contact is at *H*, the rheostat controlling the lamp current is operated by the hand wheel *K*, and voltage applied to the lamp used as source is read from the voltmeter *V*.

In Fig. 12 is shown another variation of the same type of

Fig. 12.



sensitometer, a stepped shutter plate *C*, being used instead of the straight edge type employed in the instruments previously described. The plate holder carrying the photographic plate is inserted at *A*, in the hinged back *E*, which in use folded up against the frame *F*, thus holding the photographic plate in position directly behind the shutter plate *C*. Exposure takes place through the slot *B*. The shutter plate *C*, when either in the initial or final positions, completely covers slot *B*, thus protecting the sensitive material from action of the exposing light. Each time the solenoid *G* is energized the shutter plate is moved one step to the right. Handle *D* is provided for pulling the shutter plate back

to its starting position. This type has the advantage that no auxiliary device for terminating the exposure at a precise instant of time is necessary, this being done by the last of the series of impulses applied to the solenoid by the contact maker which moves the shutter plate into a position such that it covers the slot *B* through which exposure takes place. On the other hand, it has the disadvantage that only one strip can be exposed at a time, which is a serious objection where it is necessary to expose a large number of strips. The number of strips exposed simultaneously could be considerably increased by increasing the horizontal dimension of each step of the shutter plate, but such procedure, if pursued to any extent, would result in an excessively long shutter plate and increase the burden of the solenoid by making it necessary to move the shutter plate through a considerable distance at each impulse. This instrument may also be operated from the central station, shown in Fig. 5, the solenoid, *G*, Fig. 5, being eliminated and the auxiliary contact and the offset opening *G*, Fig. 3, being used merely to de-energize the magnetic clutch and stop the movement of the film band.

PERFORMANCE TEST.

In order to determine the precision obtainable with these sensitometers the following series of tests were made. A pair of contact prints were mounted on one of the exposing machines in such a way that the movement of the solenoid under the action of the impulse from the contact maker closed an electric circuit operating one of the pens of a chronograph, the other pen being operated by a pendulum adjusted to a period of one second. A film band was carefully punched to give a series of exposures increasing by powers of 2. This was placed in position and three complete runs made, the time intervals being determined by comparing the records made by the two pens on the chronograph sheet. When operated at normal speed the second interval on the chronograph was about 1 cm. long. This gave sufficient precision for time intervals greater than four seconds, but for shorter times the chronograph drum was geared up so as to give distance of approximately 5 cm. per second. In the following table are given the results of three independent sets of values determined in this way, the group of longer time intervals being determined with the chronograph operating at normal speed and those relative to

shorter intervals with the drum rotating approximately five times as fast. It will be noted that in the first group the mean error is +.25 per cent., while in the group of shorter intervals the mean error is −.35 per cent. The fact that all of the errors in the first case are positive is due to the fact that the governed motor was running at slightly too low a speed, while in the case of the shorter periods, an effort having been made to correct the error noted, the speed was slightly too great. The main difficulty in obtaining precisely timed intervals seems to lie in the adjustment and performance of the constant speed motor rather than in the perforation of the tape and action of the contact-making mechanism. However, the errors shown in Table I are so much smaller than other errors encountered in sensitometric work as to be quite negligible.

Table I.

Computed Values	Observed Values (Records) 1st	2nd	3rd	Mean	Error per cent
128 seconds	128.1	128.3	128.3	128.2	+.16
64 seconds	64.10	64.15	64.16	64.14	+.22
32 seconds	32.07	32.08	32.12	32.09	+.28
16 seconds	16.01	16.03	15.99	16.01	+.06
8 seconds	8.03	8.01	8.02	8.02	+.25
4 seconds	4.00	4.04	4.03	4.02	+.50
				Mean	+.24
8 seconds	8.00	7.98	7.98	7.99	—.12
4 seconds	3.99	4.00	3.98	3.99	—.25
2 seconds	1.99	1.98	1.99	1.99	—.50
1 second	0.996	0.992	0.998	0.995	—.50
0.5 second	0.496	0.497	0.500	0.498	—.40
				Mean	—.35

COMPARATIVE RESULTS.

As stated previously, it was found when using the sensitometers of the sector-wheel type giving intermittent exposures, that an increase or decrease in the exposure time did not produce a proportional increase or decrease in the speed values obtained. Such discrepancies are due to the intermittency effect, the existence of which is well known. (See previous references 12, 13, 14 and 15.) These errors are eliminated by use of the non-intermittent exposing machines described in this paper. That no such effect can exist with this type of instrument is entirely obvious from a theoretical consideration of the subject, but in order to

prove the point experimentally a series of tests were made, using record tapes punched to give different exposure times. All gave exposures increasing by powers of 2, the first or normal (N) giving an exposure of 80 seconds to the area of maximum exposure. In the cases of the other record tapes used No. 2 ($2N$) gave 160, No. 3 ($4N$) gave 320, and No. 4 ($8N$) gave 640 seconds to the corresponding areas of the sensitometer strips. The results are shown in Table II.

TABLE II.

No.	Tape	Time (Max.)	Speed	Δ S	γ	$\Delta\gamma$
1	N	80	10.8	+ .25	0.92	— .06
2	$2N$	160	10.6	+ .05	1.00	+ .02
3	$4N$	320	10.4	— .15	1.00	+ .02
4	$8N$	640	10.4	— .15	1.00	+ .02
Mean			10.55		.98	

It will be noted that both speed and gamma values are independent of absolute value of the exposure time.

The results of a similar series of tests made on the intermittent sensitometer are shown in Table III, together with a determination made on the non-intermittent machine. It will be noted that a decided decrease in speed occurs as the exposure time is increased, while the gamma values for fixed time of development increase slightly. The speed obtained by non-intermittent exposure is higher than any measured by the intermittent method, while the gamma value is decidedly less.

TABLE III.

No.	Exp.	Time (Max.)	Speed	γ
1	$\frac{1}{8}N$	10	107.0	2.12
2	$\frac{1}{4}N$	20	95.5	2.19
3	$\frac{1}{2}N$	40	83.8	2.23
4	N	80	73.0	2.27
5	$2N$	160	60.8	2.25
6	$4N$	320	49.5	2.29
		Non-intermittent.		
7	N	80	125.4	1.43

In Fig. 13 is shown the general relation between the characteristic curve determined on the sector-wheel sensitometer and that obtained by the non-intermittent method (Fig. 13), curve B being that given by the former and A by the latter instrument.

It will be noted that the density difference between the two curves becomes greater as the exposure diminishes. It will be remembered that the sector-wheel diminishes the exposure from step to step by use of slots of smaller and smaller angular dimensions, so that the ratio of the rest interval to the exposure interval for each revolution of the sectors become greater toward the low exposure end of the strip. The loss of density due to intermittency is therefore proportional to the ratio of rest to exposure. This is in agreement with the work of Schwarschild and Abney (*loc cit.*).

The magnitude of the intermittency effect varies to a great extent for different kinds of plates. This is shown by the data given in Table IV. The various plates used are designated by letter as follows:

A. Very slow ordinary.
B. Very slow ordinary.
C. Medium speed panchromatic.
D. Medium speed ordinary.
E. Fast ordinary.
F. Fast ordinary.

Table IV.

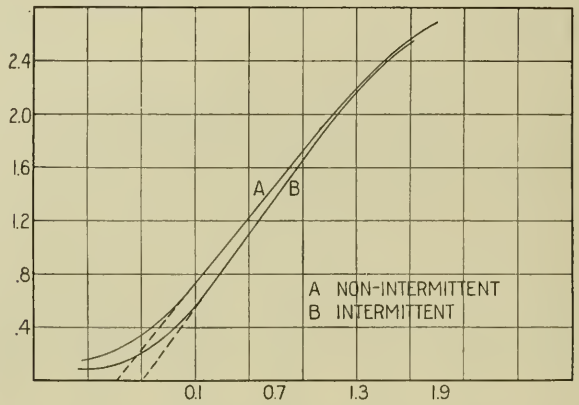
Time (Max.)	A	B	C	D	E	F
20	...	...	131	115	107	210
40	...	...	115	108	103	140
80	100	100	100	100	100	100
160	99	93	83	90	96	75
320	97	83	68	79	90	55
Non-intermittent.						
80	103	100	171	107	102	189

The speed values obtained by the sector-wheel sensitometer with normal exposure are in each case taken as 100, and all others expressed relative to those values.

The data given in Tables II, III and IV serve to show the relative performance of the sector wheel and non-intermittent instrument. It will be noted that a considerable discrepancy exists between the relative values determined with the non-intermittent sensitometer and those determined by means of the sector-wheel instrument. Further, that the relative values determined by the sector instrument are dependent upon the absolute value of the exposure time taken as a standard.

The sensitometers of Type 2, Class B, described in this paper, have been in use in this Laboratory for some time. Some of them were constructed as early as 1916, and have been in continuous use since that time. In general, they have proven extremely satisfactory, although of course certain defects were present in the first models constructed. Although a certain amount of attention is required to keep them in good running condition, they have not given much trouble in that respect, and do not require highly skilled operators. The instruments operated from the central station, shown in Fig. 5, are especially adapted for routine work and are almost entirely automatic in their action,

FIG. 13.



it only being necessary to close the main switch supplying the current to the 110 circuit and to depress the working key on the exposing machine. The action from that time on is entirely automatic and is automatically terminated, when the desired series of exposures has been impressed on the photographic plate.

The data presented in this paper are fragmentary and not intended as a treatment of the subject on the intermittency effect, but only to illustrate the difference between the results obtained with sector wheel and non-intermittent sensitometers. A considerable amount of data has already been accumulated which, together with the results of further work now in progress, the author hopes in the near future to present in a paper dealing with the general subject of intermittency.

In closing, the author desires to acknowledge his indebtedness

to Dr. W. W. Sleator for the chronographic tests of the timing mechanism and to Mr. Emory Huse for the experimental work in obtaining the sensitometric data given in the latter part of the paper.

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September 13, 1919.

French Railroad Construction During the War. (*La Nature*, January 3, 1920.)—The war naturally stopped all extensions of railways except those of great importance. There were two new lines completed on the Paris-Lyons-Mediterranean System. The first runs from Frasne, Department Doubs, to Vallorbe in Switzerland. It shortens the route from Paris to Milan. Though its length is only 15 miles, two considerable difficulties of construction had to be overcome. The marsh of Sainte-Marie had peat and mud to a depth of 200 feet, and was crossed on a filling of rocky material resting on the quagmire, which was forced into waves on both sides of the line. Mont d'Or was pierced by a tunnel more than three miles long. At one place a flow of water amounting to 1300 gallons per second was encountered, and later a second flow of twice the former amount interfered with operations.

The other line finished in war time was near Marseilles and completed a second trunk line from Paris to the Mediterranean port. Its outstanding feature is a metallic viaduct across the Lake of Caronte of half a mile length with a turn-bridge at the maritime canal.

G. F. S.

The Detection of Invisible Objects by Heat Radiation. S. O. HOFFMAN. (*Phys. Rev.,* August, 1919, p. 163.)—In 1918 the United States Army started to devise methods for detecting men and inanimate objects which were at a higher temperature than adjacent things by means of the emitted radiation. A thermopile was placed at the focus of a parabolic mirror. The radiation from the warmer object fell on the mirror and was reflected to the thermopile where it produced an electric current which was observed by means of a galvanometer. It was possible to detect a man 600 feet away. "A man lying in a depression in the ground at a distance of 400 feet was detected unfailingly as soon as he showed the upper part of his face above ground." Secret signalling could be carried on by covering and uncovering the face. This apparatus was sent to the A. E. F. in August, 1918.

An aeroplane at an altitude of 3500 feet could be picked up by such an instrument and its course followed. A wisp of cloud produced confusion by causing as large a deflection as the aeroplane did, but the two possible causes were different in the way in which the galvanometer deflection began.

G. F. S.

The Use of Electricity in Agriculture: With Special Reference to Its Development in Germany. J. F. CROWLEY. (*Journal of the Royal Society of Arts,* October 10, 1919.)—There has been an astonishing increase in the application of electricity to agricultural operations in Germany during the present century. In Saxony, at least, electricity was thus employed to a larger extent by small or moderate holders rather than by large farmers. Rural coöperative societies are common. In 1901 there was one; in 1913 more than 600. Some societies develop electrical current themselves, while others merely distribute it.

On each hundred acres of cultivated land:

(1) The British farmer feeds from 40 to 50 persons, the German farmer feeds from 70 to 75 persons.

(2) The British farmer grows 15 tons of corn, the German farmer grows 33 tons.

(3) The British farmer grows 11 tons of potatoes, the German farmer grows 55 tons.

(4) The British farmer produces 4 tons of meat, the German farmer produces 4¼ tons.

A chief factor in favor of the German farmer is his increased use of artificial fertilizers.

G. F. S.

In the *Journal of the Royal Society of Arts* for October 17, 24, and 31, 1919, is published a series of three Cantor lectures on "Coal and Its Conservation," by WILLIAM A. BONE. It will be remembered that this eminent authority lectured at THE FRANKLIN INSTITUTE a few years ago.

THE RELATIVE MERITS OF MONOCULAR AND BINOCULAR FIELD-GLASSES.* †

THE RESULTS OF AN INVESTIGATION UNDERTAKEN BY THE SUB-COMMITTEE OF THE NATIONAL RESEARCH COUNCIL ON "MONOCULAR *versus* BINOCULAR FIELD-GLASSES."

BY

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W. WENIGER.

PART III.

Field Tests at Camp Meade, Maryland.

The work herein reported consists of practical field tests conducted with monocular and binocular glasses of identical optical design. The binoculars were of the type EE, Bausch & Lomb Co., 6-power, the left limb being fitted with a mil scale and an Eames aiming scale. For the purpose of a strictly comparative test this last detail is superfluous and undesirable, presumably causing a certain interference with vision to an undetermined degree not present in the case of the monoculars, but it had to be admitted since there were no other glasses available. The monoculars were without this, being exactly like the right limb of the binoculars devoid of all (to them) superfluous parts.

The tests were four in number:

(1) A general daylight test, in which a single man was the object of vision,

(2) A twilight test, similarly planned, but carried out late in the day until terminated by darkness,

(3) A counting test, in which groups of men varying in number appeared at stated places, and

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* Communicated by Edward P. Hyde.

† Concluded from p. 223, Vol. 189, February, 1920.

[1] The Committee is indebted to Messrs. Cobb and Weniger for practically all of the experimental work.

(4) A timing test, in which the time was determined required to get the glass from the place where it is usually carried and report on an object resolvable only with the glass.

In addition, one other item is here discussed.

(5) The opinions of the observers as to the relative advantage of the two types of glasses and their reasons for the same.

For the first three of these, the observers, forty-eight in number, or a few less than this, were officers ranking from second lieutenant to captain. As nearly as possible, one-half of this number were equipped with binoculars, the other half with monoculars; exchanges were made in the course of the work in such a way as to give each observer the same amount of work with each, and to have his work with each of the two types of glass distributed as nearly as possible in the same way over the whole course of experimentation.

The purpose of the test was explained to the observers and detailed instructions were given them concerning the adjustments of the two types of glass and the method of holding each so as to obtain maximum steadiness by resting the fingers against the forehead or against the forehead and nose. Special stress was laid on the fact that when using the monocular the eye not in use should be kept open to avoid eye-strain, as well as to induce the least disturbance of the pupil; and that the best means of accomplishing this and, at the same time, of permitting focussing and attaining maximum steadiness was to hold the monocular with the objective at higher level than the eye-piece, using the left hand for the right eye or *vice versa*, thus bringing the wrist in front of the unused eye, placing the little finger below the objective mounting, the second and third fingers on the top of the instrument and gripping the eye-piece housing between the forefinger and thumb.

The visual objects upon which these three tests depend were men in khaki uniform, eleven in number, ten privates and one sergeant. They appeared at fixed points in the field, according to a prearranged program which was not the same for any two runs. For tests (1) and (2), however, the general plan of the program was the same, and it will be described in detail once for both.

The ground used for tests (1), (2), and (3) lies in the eastern part of Camp Meade, the observers being located (see map, Fig. 10) on the top of a low, broad hill situated in the bend of the

concrete road which leads eastward from the W. B. & A. loop station and turns toward the north. The observers looked in a northerly direction, somewhat easterly, and were given complete freedom in choosing their posture. Many of them were seated on camp chairs and other suitable articles after the first day. The appearance of the landscape is shown in the photograph (Fig. 11) where also are shown the various locations of the men who acted as visual objects, designated by capital letters. The location of these stations is similarly indicated on the map.

In the daylight and the twilight work, tests (1) and (2), but one man appeared at a time, coming from a concealed position to his designated place of exposure, according to schedule, standing there facing the observer for fifty seconds, and then either raising an arm to the horizontal or aiming a rifle, to the left or to the right as the schedule called for, for ten seconds. This applies to the men at Stations *A, B, C, D, E, F, G,* and *H*. The man at *E* was located in the woods and could only be seen between the tree-trunks. His action consisted in walking a certain exposed beat for one minute, either without a rifle or with a rifle at right shoulder. In the cases of *X, Y,* and *Z* the action consisted in either aiming a rifle or pointing with the hand at the observers.

The conditions as to distance, background, etc., under which the men at each of these stations was to be seen are given in the following summary:

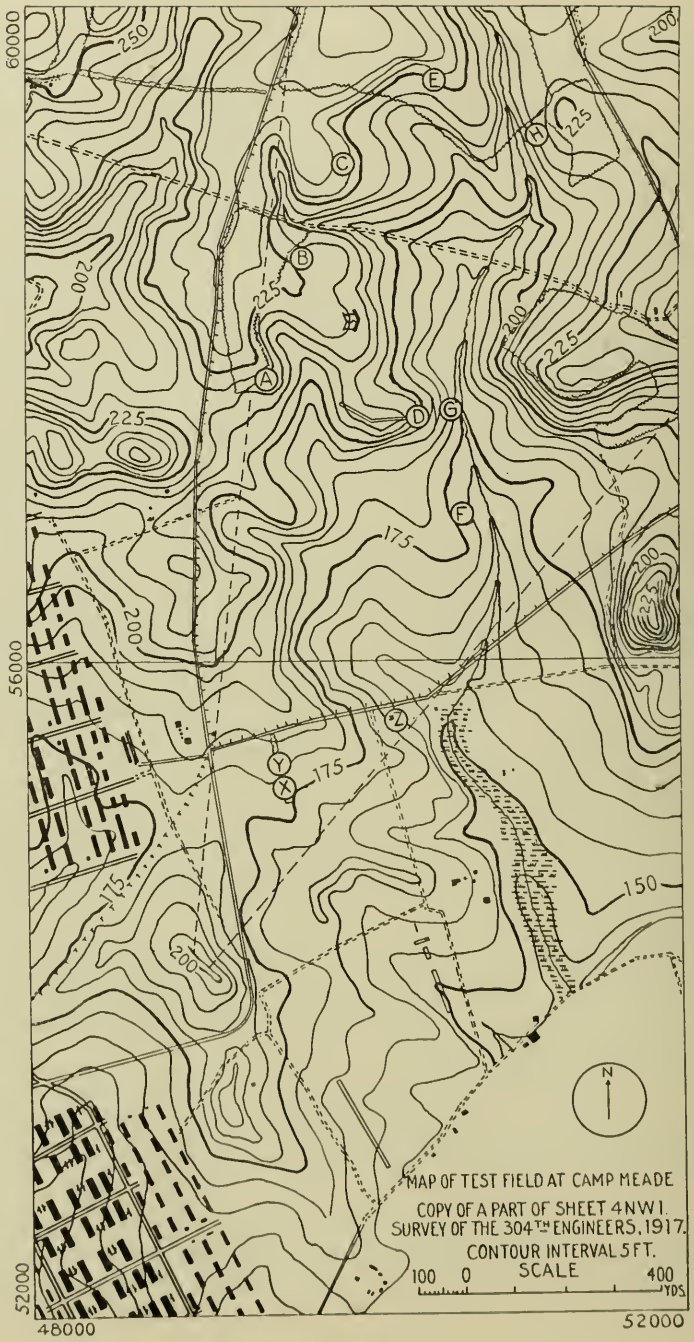
A—1180 yards. Seen against meadow hillside about 150 to 200 feet beyond him. Stands among small bushes, not concealed by them. Not much stereoscopic effect noted on viewing with binoculars.

B—1440 yards. Concealed from waist line down by intervening elevation; background is a spur of the wood about 100 feet beyond, appearing quite near to him as seen through the binocular. No stereoscopic effect noted.

C—1650 yards. Full length; background up to waist is the meadow which rises from his feet, above that a darker ground, apparently cleared forest bottom. Little or no stereoscopic effect.

D—1190 yards. Concealed to crotch by the trench in which he stands. Background is a meadow slope estimated from the map to be about 500 yards beyond. Distinct to good stereoscopic effect.

Fig 10.


60000
56000
52000
48000
52000
250
200
225
175
150
A
B
C
D
E
F
G
H
X
Y
Z
N
MAP OF TEST FIELD AT CAMP MEADE
COPY OF A PART OF SHEET 4NW1.
SURVEY OF THE 304TH ENGINEERS, 1917.
CONTOUR INTERVAL 5 FT.
SCALE
100 0 400
YDS

E—1850 yards. In wood, rather deeply in. Concealed in part of his beat, sometimes entirely visible between tree-trunks. No stereoscopic effect.

F—1055 yards. Concealed crotch-high.

G—1230 yards. Concealed to mid-thighs.

F and *G* are both concealed, as above, by intervening swells in the meadow. Background conditions also about alike; nearly level meadow. Little or no stereoscopic relief.

H—1800 yards. Completely exposed. Seen against the slope which ascends easily behind him. No stereoscopic effect.

FIG 11.

Experimental field. Stations are indicated by circles and letters. Note: Second observer from left is holding monocular incorrectly.

X—410 yards. Concealed to an oblique line, about breast-high, by the hedge. Background about as for *Y*.

Y—420 yards. Nearly full length, screened by the hedge, especially below. The details of the hedge are seen with fair stereoscopic effect against the level meadow beyond.

Z—630 yards. Concealed breast-high by intervening elevation when standing in the open at the northwest or southeast corner of a house. In half of his events *Z* appeared in the west or south window of the house. As the outside and inside conditions are not at all comparable as to light, background, etc., the latter have, in the report, been given the separate designation *Z'*.

(1) THE DAYLIGHT TESTS.

The daylight tests were run on four days: March 18th, from 2 P.M. to 5 P.M., and March 19th, 20th, and 26th, from 2 P.M. to 4:30 P.M. Each man who acted as visual object appeared eight times each day. The two postures, raising the arm and aiming the rifle, and the two directions, east and west, making four possibilities for most of the men. A program was arranged consisting of four events for each man—forty-four events in all in shuffled order—and after a short intermission in which monoculars and binoculars were exchanged by the observers the whole forty-four events were repeated in reverse order. Thus each observer had the opportunity of seeing all the different events of that day once with a monocular and once with a binocular. He was to record the time and the place at which he saw the man (*A, B, C,* etc.) and what he saw the man do.

On March 18th the program was arranged to have one event every two minutes. It was found that this interval was longer than was necessary. For the other days and for the twilight work it was shortened to ninety seconds. This gave adequate time for recording and had the further advantages of keeping the observers more interested and shortening the whole time of work. As was to be expected, on the first day a considerable portion of the time, at first, was required for the observers to learn the stations. To facilitate this all the men out in the field were required to be in their respective exposed positions for fourteen minutes, until within a minute of the time for the first scheduled event. More or less confusion was, however, inevitable, especially as there were many other men, extraneous to this work, about the field engaged in various kinds of practice. As a result the records showed many entries which proved by comparison with the schedule to be irrelevant and had to be excluded. These things disappeared rapidly as the work went on. The observer's problem then became simple: he had to watch eleven points in the landscape and report in his record the time, place and action when a man appeared at any one.

Table XI is a general summary of these results. In compiling this table certain eliminations had to be made in advance in order that the results might apply equally to monoculars and binoculars. On the first day there was delay in learning the field, and the

program was too long and had to be cut short at the end. Fortunately, since the second half of the program was exactly the reverse of the first, the resulting deletions did not involve much valuable material. Again, there was delay, after the intermission, in getting the observers back to work. This showed itself in the summary for the day and the necessary deletions could be estimated and equalized. In a few cases other duties or circumstances made the record of a single observer incomplete. The first consideration in making these deletions was always to make the total number of experiments equal and identical for the two glasses; the second was to have each observer's final record represent equal numbers of experiments with the two. It was only to the slightest extent that the second could not be realized. The following figures have reference only to the remaining experiments considered in Table XI and such other things as occurred while these were in progress.

	Monocular	Binocular
Experiments considered	7,174	7,174
Total records	5,005	5,295
Records considered	4,726	5,047
Records rejected as extraneous	279	248

This speaks at once in favor of the binocular, in two ways. Out of a total of 7174 possibilities the number of times that the test objects were seen is more numerous by 321 (5047 – 4726), or 4.5 per cent. of the possibilities. In addition, the records not applying to the test objects of the experiments are less numerous with the binocular by 31, indicating, if anything, that the problem of learning the field was simpler with the binocular.

EXPLANATION OF TABLES XI AND XII.

Column Headings.

A, B, C, etc.—Designations of stations.

S – Observation of the man at Stations *A, B, C,* etc.

ew – Discrimination of the direction of action (aiming or extending arm) at right angles to the observer's line of sight. See also explanation of line heading "results."

TABLE XI.

Daylight Results, Camp Meade, March 18 to 26, Arranged According to Calendar Days.

		A						B						C					
		Monocular			Binocular			Monocular			Binocular			Monocular			Binocular		
		S	ew	ro	S	ew	ro	S	ew	ro	S	ew	ro	S	ew	ro	S	ew	ro
Mar. 18	Experiments	95	95	95	95	95	95	95	95	95	95	95	95	143	143	143	143	143	143
	Results	79	45	43	80	53	49	29	7	2	28	13	12	115	29	2	119	42	0
	Percentages	83.1	57.0	54.4	84.2	66.2	61.3	30.5	24.2	6.9	29.4	46.4	42.8	80.4	25.2	1.7	83.2	35.3	0.0
Mar. 19	Experiments	176	176	132	176	176	132	175	175	175	175	175	175	175	175	175	175	175	175
	Results	163	114	75	162	118	83	45	13	6	57	29	27	158	28	28	168	53	47
	Percentages	92.6	70.0	61.3	92.1	72.9	68.2	25.7	28.9	13.3	32.6	50.9	47.4	90.2	17.7	17.7	96.0	31.5	28.0
Mar. 20	Experiments	188	188	188	188	188	188	186	186	186	186	186	186	188	188	188	188	188	188
	Results	175	123	87	177	146	90	48	15	18	56	22	24	179	68	59	183	81	79
	Percentages	93.1	70.2	49.7	94.2	82.5	50.9	25.8	31.3	37.5	30.1	39.3	42.8	95.2	38.0	33.0	97.4	44.2	43.1
Mar. 26	Experiments	172	172	172	172	172	172	172	172	172	172	172	172	172	172	172	172	172	172
	Results	145	67	68	156	93	105	89	27	21	92	34	27	151	33	12	154	56	40
	Percentages	84.3	46.1	46.9	90.7	59.6	67.3	51.7	30.3	·23.6	53.4	37.0	29.4	87.7	21.9	8.0	89.5	36.4	26.0
	Experiments	631	631	587	631	631	587	628	628	628	628	628	628	678	678	678	678	678	678
Totals results		562	349	273	575	410	327	211	62	47	233	98	90	603	158	101	624	232	166

		D						E				F					
		Monocular			Binocular			Monocular		Binocular		Monocular			Binocular		
		S	ew	ro	S	ew	ro	S	ro	S	ro	S	ew	ro	S	ew	ro
Mar. 18	Experiments	143	143	143	143	143	143	190	190	190	190	190	190	190	190	190	190
	Results	79	46	34	100	77	54	42	2	56	3	71	39	34	71	34	30
	Percentages	55.2	58.2	43.0	69.9	77.0	54.0	...	...	...	...	37.4	55.0	47.8	37.4	47.8	42.2
Mar. 19	Experiments	179	179	179	179	179	179	178	178	178	178	178	178	178	178	178	178
	Results	157	124	99	159	139	128	10	0	30	1	163	129	98	172	141	129
	Percentages	87.6	79.2	63.0	88.8	87.4	80.5	...	...	...	...	91.5	79.1	60.1	96.6	82.0	75.0
Mar. 20	Experiments	187	187	187	187	187	187	187	187	187	187	187	187	187	187	187	187
	Results	183	156	134	178	163	145	38	0	57	—1	181	152	145	183	167	149
	Percentages	97.9	85.2	73.2	95.2	91.6	81.5	...	...	...	...	96.9	84.0	80.1	97.9	91.2	81.4
Mar. 26	Experiments	129	129	129	129	129	129	129	129	129	129	172	172	172	172	172	172
	Results	79	45	34	84	53	43	51	0	68	1	160	133	123	164	147	140
	Percentages	61.2	56.9	43.0	65.1	63.1	51.2	...	...	...	...	93.0	83.1	76.9	95.3	89.7	85.3
	Experiments	638	638	638	638	638	638	684	684	684	684	727	727	727	727	727	727
Totals results		498	371	301	521	432	370	141	2	211	4	575	453	400	590	489	448

		G						H						X					
		Monocular			Binocular			Monocular			Binocular			Monocular			Binocular		
		S	ew	ro	S	ew	ro	S	ew	ro	S	ew	ro	S	p	ro	S	p	ro
Mar. 18	Experiments	143	143	143	143	143	143	143	143	143	143	143	143	143	143	143	143	143	143
	Results	52	19	16	79	49	39	63	19	21	69	34	27	91	3	3	87	6	6
	Percentages	36.4	36.5	30.8	55.2	62.0	49.4	44.0	30.2	33.3	48.2	49.3	39.1	63.6	3.3	3.3	60.8	6.9	6.9
Mar. 19	Experiments	179	179	179	179	179	179	134	134	134	134	134	134	177	177	177	177	177	177
	Results	127	73	63	142	108	96	91	27	11	93	33	24	147	28	24	157	41	17
	Percentages	70.9	57.5	49.6	79.3	76.1	67.6	67.9	29.6	12.1	69.4	35.5	25.8	83.0	19.0	16.3	88.7	26.1	10.8
Mar. 20	Experiments	140	140	140	140	140	140	187	187	187	187	187	187	188	188	188	188	188	188
	Results	111	80	74	122	94	91	148	69	49	166	86	60	76	3	3	70	4	4
	Percentages	79.3	72.1	66.7	87.2	77.0	74 6	79.2	46.6	33.1	88.8	51.8	36.2	40.4	3.9	3.9	37.2	5.7	5.7
Mar. 26	Experiments	129	86	86	129	86	86	172	172	172	172	172	172	129	129	129	129	129	129
	Results	95	34	47	100	39	52	160	75	69	157	100	79	110	9	1	115	9	5
	Percentages	73.6	53.7	74.2	77.5	58.5	78.0	93.0	46.9	43.1	91.3	63.7	50.3	85.2	8.2	0.9	89.1	7.8	4.3
Totals	Experiments	591	548	548	591	548	548	636	636	636	636	636	636	637	637	637	637	637	637
	results	385	206	200	443	290	278	462	190	150	485	253	190	424	43	31	429	60	32

		Y						Z						Z′					
		Monocular			Binocular			Monocular			Einocular			Monocular			Binocular		
		S	p	ro	S	p	ro	S	p	ro	S	p	ro	S	p	ro	S	p	ro
Mar. 18	Experiments	144	144	144	144	144	144	96	96	96	96	96	96	95	48	48	95	48	48
	Results	21	5	−1	40	9	5	69	28	28	74	38	36	25	2	2	43	7	7
	Percentages	14.6	23.8	−4.8	27.8	22.5	12.5	71.8	40.6	40.6	77.1	51.4	48.6	26.3	16.0	16.0	45.2	32.3	32.3
Mar. 19	Experiments	177	177	177	177	177	177	88	88	88	88	88	88	90	90	90	90	90	90
	Results	122	62	11	138	88	24	69	17	13	66	16	12	54	5	5	67	5	3
	Percentages	68.9	50.8	9.0	78.0	63.7	17.4	78.4	24.6	18.8	75.0	24.2	18.2	60.0	9.3	9.3	74.4	7.5	4.5
Mar 20	Experiments	188	188	188	188	188	188	94	94	94	94	94	94	94	94	94	94	94	94
	Results	125	33	19	136	43	35	90	29	27	88	41	35	92	15	7	86	19	15
	Percentages	66.5	26.4	15.2	72.4	31.6	25.8	95.8	32.2	30.0	93.6	46.6	39.8	97.9	16.3	7.6	91.5	22.1	17.4
Mar. 26	Experiments	129	129	129	129	129	129	86	86	86	86	86	86	43	43	43	43	43	43
	Results	85	14	8	86	17	17	82	47	37	80	49	49	31	11	1	32	11	7
	Percentages	65.9	16.5	9.4	66.6	19.8	19.8	95.4	57.3	45.1	93.0	61.2	61.2	72.1	35.5	3.2	74.4	34.4	21.9
Totals	Experiments	638	638	638	638	638	638	364	364	364	364	364	364	322	275	275	322	275	275
	results	353	114	37	400	157	81	310	121	105	308	144	132	202	33	15	228	42	32

TABLE XII.

Daylight Results, Camp Meade, March 18 to 26, Arranged According to Days of Practice.

	A						B						C					
	Monocular			Binocular			Monocular			Binocular			Monocular			Binocular		
	S	*ew*	*ro*	*S*	*ew*	*ro*	*S*	*ew*	*ro*	*S*	*ew*	*ro*	*S*	*ew*	*ro*	*S*	*ew*	*ro*
I Experiments	140	140	136	140	140	136	140	140	140	140	140	140	188	188	188	188	188	188
I Results	114	64	58	121	80	52	37	9	3	38	19	18	153	34	9	162	51	8
I Percentages	81.4	56.1	52.3	86.4	66.1	44.2	26.4	34.3	8.1	27.2	5.0	47.4	81.4	22.2	5.9	86.1	31.5	4.9
II. Experiments	187	187	147	187	187	147	186	186	186	186	186	186	186	186	186	186	186	186
II. Results	178	126	83	170	127	104	50	16	11	59	25	24	171	31	30	180	64	58
II. Percentages	95.2	70.7	59.4	90.8	74.7	78.0	26.9	32.0	22.0	31.7	42.4	40.7	91.9	18.1	17.5	96.8	35.6	32.2
III Experiments	156	156	156	156	156	156	154	154	154	154	154	154	156	156	156	156	156	156
III Results	145	103	74	146	119	73	42	14	14	52	24	25	150	66	52	148	73	66
III Percentages	92.9	71.0	51.0	93.6	81.5	50.0	27.2	33.3	33.3	33.8	46.2	48.1	96.2	44.0	34.6	94.9	49.3	44.6
IV Experiments	148	148	148	148	148	148	148	148	148	148	148	148	148	148	148	148	148	148
IV Results	125	56	58	138	84	98	82	23	19	84	30	23	129	27	10	134	44	34
IV Percentages	84.5	44.8	46.4	93.3	60.8	71.0	55.4	28.0	23.2	56.7	25.7	27.4	87.2	20.9	7.8	90.5	32.8	25.4
Experiments	631	631	587	631	631	587	628	628	628	628	628	628	678	678	678	678	678	678
Totals Results	562	349	273	575	410	327	211	62	47	233	98	90	603	158	101	624	232	166

	D						E				F					
	Monocular			Binocular			Monocular		Binocular		Monocular			Binocular		
	S	*ew*	*ro*	*S*	*ew*	*ro*	*S*	*ro*	*S*	*ro*	*S*	*ew*	*ro*	*S*	*ew*	*ro*
I Experiments	189	189	189	189	189	189	236	236	236	236	237	237	237	237	237	237
I Results	113	68	56	138	108	67	45	2	63	3	112	68	61	115	71	55
I Percentages	59.8	60.2	44.2	73.0	78.2	48.5	19.1	4.4	26.7	4.8	47.2	60.7	54.4	48.5	61.7	47.8
II Experiments	188	188	188	188	188	188	187	187	187	187	187	187	187	187	187	187
II Results	175	143	120	171	150	147	13	0	34	1	173	138	113	181	150	140
II Percentages	93.0	81.6	68.5	90.9	87.7	86.0	7.0	0.0	18.2	2.9	92.5	79.8	65.3	96.8	82.9	77.4
III Experiments	150	150	150	150	150	150	150	150	150	150	155	155	155	155	155	155
III Results	145	120	102	137	125	115	36	0	58	−1	153	133	122	151	140	128
III Percentages	96.6	82.8	70.4	91.3	91.2	83.9	24.0	0.0	38.7	−1.7	98.7	86.9	79.7	97.4	92.7	84.7
IV Experiments	111	111	111	111	111	111	111	111	111	111	148	148	148	148	148	148
IV Results	65	40	29	75	49	41	47	0	56	1	137	114	104	143	128	125
IV Percentages	58.5	61.5	44.6	67.6	65.3	54.6	42.4	0.0	50.4	1.8	92.6	83.2	75.9	96.6	89.5	87.4
Experiments	638	638	638	638	638	638	684	684	684	684	727	727	727	727	727	727
Totals Results	498	371	301	521	432	370	141	2	211	4	575	453	400	590	489	448

		G						H						X					
		Monocular			Binocular			Monocular			Binocular			Monocular			Binocular		
		S	ew	ro	S	ew	ro	S	ew	ro	S	ew	ro	S	p	ro	S	p	ro
I	Experiments	183	182	182	183	182	182	185	185	185	185	185	185	188	188	188	188	188	188
	Results	71	29	22	105	63	49	89	27	25	94	45	33	114	6	4	108	8	4
	Percentages	38.8	41 0	31.2	57.4	60.3	46.9	48.1	30.3	28.1	50.8	47.9	35.1	60.6	5 3	3.5	57.5	7.4	3.7
II	Experiments	181	181	181	181	181	181	148	148	148	148	148	148	187	187	187	187	187	187
	Results	132	80	72	145	111	105	105	31	19	111	41	28	140	27	25	152	40	20
	Percentages	72.9	60.6	54.5	80.1	76.5	72.4	71 0	29.5	18.1	75.0	36.9	25.2	74 8	19.3	17.9	81.2	26.3	13 2
III	Experiments	116	111	111	116	111	111	155	155	155	155	155	155	151	151	151	151	151	151
	Results	103	71	69	106	82	79	132	70	44	146	79	61	75	4	2	69	3	3
	Percentages	88 8	72.0	70.1	91.4	80.8	77.9	85.1	53.0	33.3	94.1	54.1	41.8	49.7	5.3	2.7	45.7	4 3	4 3
IV	Experiments	111	74	74	111	74	74	148	148	148	148	148	148	111	111	111	111	111	111
	Results	79	26	37	87	34	45	136	62	62	134	88	68	95	6	0	100	9	5
	Percentages	71.2	40.3	70.3	78.4	58.5	77.5	91.9	45.6	45.6	90.5	65.7	50.7	85.6	6.3	0 0	90.0	9 0	5.0
Totals	Experiments	501	548	548	591	548	548	636	636	636	636	636	636	637	637	637	637	637	637
	Results	385	206	200	443	290	278	462	190	150	485	253	190	424	43	31	429	60	32

		Y						Z						Z′					
		Monocular			Binocular			Monocular			Binocular			Monocular			Binocular		
		S	p	ro	S	p	ro	S	p	ro	S	p	ro	S	p	ro	S	p	ro
I	Experiments	189	189	189	189	189	189	119	119	119	119	119	119	118	71	71	118	71	71
	Results	43	13	3	66	13	5	87	33	29	92	42	40	41	3	1	62	9	7
	Percentages	22.8	30.2	7.0	34.9	19.7	7.6	73.1	37.9	33.3	77.4	45.7	43.5	34.8	12.1	4.0	52.5	24.2	18 8
II	Experiments	187	187	187	187	187	187	93	93	93	93	93	93	94	94	94	94	94	94
	Results	134	62	11	145	87	27	78	18	18	74	22	18	63	9	7	70	6	4
	Percentages	71.6	46.3	8.2	77.5	60.0	18.6	83.9	23.1	23.1	79.6	29.7	24.3	67.0	14.3	11.1	74.4	8.6	5.7
III	Experiments	151	151	151	151	151	151	78	78	78	78	78	78	73	73	73	73	73	73
	Results	104	28	16	116	42	34	75	31	29	74	38	32	72	12	6	69	17	13
	Percentages	68.8	26.9	15.4	76.7	36.2	29.3	96.2	41.3	38.6	94.8	51.4	43.3	98.6	16.7	8.3	94.5	24.6	18.8
IV	Experiments	111	111	111	111	111	111	74	74	74	74	74	74	37	37	37	37	37	37
	Results	72	11	7	73	15	15	70	39	29	68	42	42	26	9	1	27	10	8
	Percentages	64.8	15.3	9.7	65.8	20.5	20.5	94.5	55.7	41.4	91.9	61.8	61.8	70.2	34.6	3.8	73.0	37.0	29.6
Totals	Experiments	638	638	638	638	638	638	364	364	364	364	364	364	322	275	275	322	275	275
	Results	353	114	37	400	157	81	310	121	105	308	144	132	202	33	15	228	42	32

ro — Discrimination between aiming and extending arm. See also explanation of line heading "results."

p — Mention of action (aiming or extending arm) in the observer's line of sight.

Line Headings.

I, II, III, IV (Table XII only)—Results obtained respectively on the first, second, third and fourth or fifth days of practice with the monocular.

Experiments.—Total number of experiments considered.

Results.—Number of records after eliminating extraneous ones. This includes in columns *S* the total number of answers; in columns *ew* and *ro* the number of right minus the number of wrong answers; in columns *p* the number of records as to action.

Percentages.—In columns *S*, the percentage of observation:

$$100 \times \frac{\text{Number of results}}{\text{Number of experiments}}$$

; in columns *ew, ro* and *p* the percentage of discrimination:

$$100 \times \frac{\text{Results } (ew, ro, p)}{\text{Results } (S)} \times \frac{\text{Experiments } (S)}{\text{Experiments } (ew, ro, p)}$$

It is a point of importance to know, if possible, just how this result would be affected by practice. It is to be presumed that all of the observers had had practice to a greater or less extent with binoculars, while as to the monoculars the presumption is all the other way. Then in the course of the work it is to be expected that this difference will tend to disappear. In Table XII, therefore, the observers have been grouped, not according to the calendar days of the experiment, as in Table XI, but according to the days which were the first, second, etc., of their individual practice with the monocular in the various parts of this work. A comparison of these two groupings is shown in the following:

Day of Practice	Total	March 18	19	20	26
I	60	48	5	6	1
II	47	..	40	7	0
III	39	..	..	34	5
IV	37	..	..	..	37
		48	45	47	43

Thus, with a total of 60 observers who figure in at least one day's work, there were but 37 who got as far as the fourth. This was, of course, due to the fact that a few of the original forty-eight had to be excused on account of other duties from time to time, their places being taken by a limited number of others. This

might be briefly stated by saying that there were 37 regular observers and 23 substitutes.

A word is to be said as to how the extraneous results were distributed over the various days. First, as to the days of the calendar we have extraneous observations:

March	Monocular	Binocular	Number of Observers	Excess in favor of Binoculars
18	104	97	48	7
19	96	82	45	14
20	56	43	47	13
26	23	26	43	− 3
	279	248		31

Day	Monocular	Binocular	Number of Observers	Excess in favor of Binoculars
I	148	127	60	21
II	75	67	47	8
III	34	28	39	6
IV	22	26	37	− 4
	279	248		31

All of the March 18th records are, of course, included in Day I, and, as has been said, the first portion of the work of that date has not been considered. The decline in the number of extraneous records is therefore greater than would be indicated by the first line of either of the above tables, since the deleted portion contains a more than proportionately large number. The process of learning the field was a rapid one, and the extraneous records of the later dates were practically all due to happenings in the field which could only be differentiated by reference to the schedule.

Before going further, it may be well to state in detail the first step in the analysis of the results. The men at Stations *A, B, C, D, F, G,* and *H,* fifty seconds after appearing in their respective exposed places, went through the performance of aiming a rifle or raising an arm to the horizontal, either to the east or to the west; that is, at right angles to the observers' line of sight. It soon developed that the observer's record, in addition to the time, which was a check on the relevancy of the report, consisted essentially of three things: (1) the station designation, (2) the direction of action, whether east or west, and (3) the nature of the action, whether the man aimed a rifle or simply raised an arm.

As to (1), there is no apparent way of rating the result except to compare the number of times a given man (test object), *e.g.*, *A*, was seen, with the total number of possibilities of that event. The symbol *S* is used here with reference to this criterion.

(2) As to the report on the direction of the action, there are three possibilities. These are: no report, wrong report, and right report. A wrong report is made, on the face of the matter, in the absence of seeing. With but two possibilities as to the fact, it is equally probable that a right report would be made in the same way, that is, for every wrong answer there are not one, but two "guesses"; and conclusions as to actual seeing are to be drawn from the number of right answers minus the number of wrongs. The symbol *ew* has reference to the seeing of the action, and the values under this head are derived from the right-minus-wrong number of answers as to direction.

(3) The case of differentiating the two actions is exactly parallel. The symbol used is *ro*, and the results under that head are derived from the difference between the numbers of right and wrong answers.

In the cases of *X*, *Y*, *Z*, and *Z'* the action consisted in either aiming a rifle or pointing at the observers. In place of the *ew* criterion, it was necessary to use here the right-plus-wrong answers, since east and west did not enter the question. In saying that he saw the man point, or aim the rifle, the observer states, although not specifically, that he saw the movement; and this is irrespective of whether he is right or wrong as to its differentiation. The symbol *p* refers to this criterion; while the right-minus-wrong number of answers as to aiming or pointing is the argument in the results under the head *ro*.

The percentages are always based on the total possibilities of the case. Under *S* this will be the total number of experiments; but under *ew*, *ro*, and *p* the total possibilities will be the number of times the man was seen. Discrimination is not possible unless the object is, in the first place, "picked up" and the glass and the eyes fairly trained upon it. The method of computation of the percentages will be treated in detail later on.

In Tables XI and XII the results are grouped by stations (*A*, *B*, *C*, etc.); in Table XI, also, by calendar days (March 18th, 19th, 20th and 26th), and in Table XII by days of practice (I, II, III, and IV). From these two tables the mean percentages were

TABLE XIII.

Weighted Mean Percentages of Correct Observation, Day by Day, for all Objects Except E. (The Values Under p, Tables XI and XII, have Been Treated like the ew Values and are Included Here.)

		March			
		18	19	20	26
S	Binocular	55.8	80.0	79.8	80.6
	Monocular	49.7	75.2	77.6	78.4
	Difference	6.1	4.8	2.2	2.2
ew	Binocular	46.7	54.7	57.9	51.0
	Monocular	36.4	46.5	50.9	43.1
	Difference	10.3	8.2	7.0	7.9
ro	Binocular	34.7	44.3	48.8	47.7
	Monocular	26.9	33.8	43.0	36.7
	Difference	7.8	10.5	5.8	11.0

		Day of practice			
		I	II	III	IV
S	Binocular	58.8	80.2	81.8	81.6
	Monocular	52.4	77.0	80.6	77.8
	Difference	6.4	3.2	1.2	3.8
ew	Binocular	44.9	55.5	60.2	50.9
	Monocular	38.0	47.1	53.4	42.3
	Difference	6.9	8.4	6.8	8.6
ro	Binocular	31.6	47.7	51.2	49.0
	Monocular	27.7	36.7	43.6	36.2
	Difference	3.9	11.0	7.6	12.8

		For all days	All except I
S	Binocular	74.70 ± 0.06	81.1
	Monocular	70.93 ± 0.07	78.4
	Difference	3.77	2.7
ew	Binocular	53.45 ± 0.05	55.8
	Monocular	45.55 ± 0.14	47.8
	Difference	7.90	8.0
ro	Binocular	45.18 ± 0.17	49.2
	Monocular	36.34 ± 0.07	38.9
	Difference	8.84	10.3

averaged for each day and the averages are given in Table XIII. These averages are plotted in Fig. 12. In computing the averages, Station *E* was omitted, for the reasons that the conditions of vision (a moving object) were not comparable to those of the other stations, and since *E* simply walked up and down with no action comparable to raising an arm or aiming a rifle, there were no data at all comparable to those under the heads *ew* and *p*. Casual examination of the results will show at once that the results in the case of *E* support the ultimate conclusions more strongly than the other results.

The weights assigned to the various stations and used in computing the averages in Table XIII were derived from the total numbers of experiments for all four days on the respective stations, Tables XI and XII, and from the similar total of the numbers of times the man was reported seen on all four days at the respective station, under the head *S*. They are, in all cases, computed from these totals for the four days in a manner similar to that in which the base for an individual percentage would be found. This will be clear if we bear in mind how the percentages in the tables were derived. To illustrate, a block from Table XI, *A*, under Monocular, March 19th, is repeated here with additions in parentheses

	Monocular		
	S	*ew*	*ro*
Experiments	176	176	132
Results	163	114	75
Per cent.	(92.6)	(64.8)	(56.8)
Percentages	92.6	70.0	61.3

to show the method of computation. The percentages in parentheses are simply each "result" on its corresponding "experiments" as a base. The final ones for *ew* and *ro* are the ones above, recomputed on the *S*-percentage, 92.6 as a base. For these final percentages as they appear in the table the bases are, therefore, respectively, 176, 163, and $163 \times \frac{132}{176}$. In just the same way the weights for *S*, *ew*, and *ro* are here, respectively, as 631, 568.5, and $568.5 \times \frac{587}{631}$. The number 568.5 is here the mean of the two numerical results under the two *S*'s for monocular and binocular, and was used in computing the weights for both alike. The weights for *A*, *B*, *C*, etc., were reduced to such a scale that the *F* weight (number of experiments = 727) should be 1.00. The

others, to lessen the amount of computation necessary to correct an error, were so scaled that the number 714 should correspond to weight unity. The weights used are:

Station	Weight S	ew	ro
A	0.87	0.77	0.72
B	.86	.30	.30
C	.93	.83	.83
D	.88	.69	.69
F	1.00	.79	.79
G	.81	.52	.52
H	.88	.64	.64
X	.88	.58	.58
Y	.88	.51	.51
Z	.50	.42	.42
Z'	.44	.25	.25

The final results for all days, Table XIII, were obtained from the two sets of day averages just described, by similarly determining the two appropriate sets of day weights and applying them. The figures added after the ± sign indicate how the two averages diverged from their mean in each case. These differences are due to small discrepancies in weighting, and are too small to affect the conclusions in any essential way. The last column of figures in Table XIII gives the results, omitting each observer's first day's results from the computation. It consists, therefore, of the appropriately weighted averages for Days II, III, and IV.

In connection with Tables XI, XII, and XIII, a brief description of the weather during each of the four experimental periods is appended.

March 18, 1918, 2 P.M. to 5 P.M.—Sky, 10/10 clear, bright sun, some haze and dust. Temperature moderate.

March 19th, 2 P.M. to 4.30 P.M.—Sky 8/10 cumulus and cirro-cumulus clouds. Gentle breeze, S.S.E., faint to bright sun, haze and dust in the distance. Air clear for sound. Haze and dust increasing during the course of the afternoon. At 4.18 P.M. the sun went behind a thick cloud. Temperature moderate.

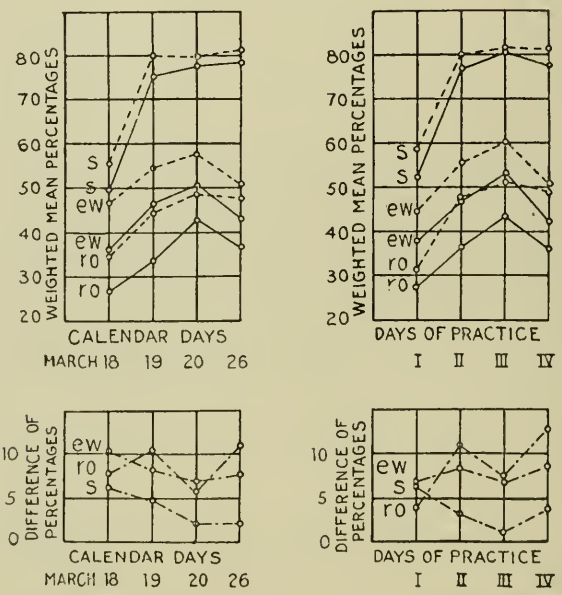
March 20th, 2 P.M. to 4.30 P.M.—Sky 8/10 cirro-cumulus and cirro-stratus clouds, faint sun. More haze than last. Sounds very plain, gentle east wind, comfortable temperature, slight heat shimmer. Increasing cloudiness.

March 26th, 2 P.M. to 4.30 P.M.—At 2 P.M., 9/10 cumulus

clouds, sun through rifts occasionally; at 2.20 P.M., 5/10 clear; at 3.30 P.M., 9/10; at 3.45 P.M., completely clear, sun still well up. Strong N.W. wind, very cold during whole time.

Discussion of the General Daylight Results.—Table XIII and Fig. 12 leave very little to be said, at least as to the fact that in the present test the binocular ran very consistently ahead of the monocular. There is a difference, however, in the way the two glasses compare as to the different criteria of the test. Under the

FIG 12.



MONOCULARS— BINOCULARS---- BINO. MINUS MONO.---
SUMMARY OF DAYLIGHT RESULTS.

head *S*, it will be noted, the differences are smaller, and also they tend, in a slight measure, perhaps, to decrease. The mode of vision upon which the results under *S* depend is quite a different one from that underlying the criteria of *ew* and *ro*. In the first case the result will depend primarily on a diligent watching of the various parts of the field and mostly, if not exclusively, upon the activity of the eccentric portions of the retina. It is essentially a process of discovery, and will be modified by many circumstances of attention as well as by the absolute ability to see. Following it, the process of orientation takes place, in which the axis of the

glass is brought into alignment and the eye adjusted for direct vision. Detailed examination of the object then takes place, during which the information is gained which goes to make the results stated under *ew* and *ro*.

How these two modes of vision behave, with respect to the use of the glass and with respect to practice, is a question which it was hoped these results would answer more definitely than they do. Where the monocular shows relative improvement with practice, as it here does, in the matter of first locating the test objects (see *S*, lower right-hand plot, Fig. 12), it is a question for further work to answer whether that relative improvement will go on to the point of equality.

As to the discrimination of details in the test object, the result is quite the other way. Here the binocular shows relative improvement (*ew* and *ro*, same plot). If the observers had previously had preponderant experience with the monocular this would not offer difficulties. The presumption is, if anything, the other way, and the relative improvement of the results obtained with the binocular, in the distinguishing of detail, is hard to interpret otherwise than as evidence of intrinsic superiority of that type of glass for that purpose under conditions such as those of this test.

The extent of the difference for Station *E* is 70 observations of the man out of 684 possibilities. This applies to criterion *S*, the *ew* being absent in this case, and the results under *ro* insignificant. This difference amounts to 10.2 per cent. as against a similar difference of 3.8 per cent. for all other stations (see last section of Table XIII).

It will be recalled that in Part I of this report it was found that all three of the observers had unequal vision in the two eyes, and that binocular vision through a binocular glass was not better than monocular vision with the better eye through the corresponding limb of the same glass. Where it showed a slight superiority in point of the frequency of right answers this was offset by a longer time consumed in observation. Indeed in one case the admission of the inferior eye caused a falling off of vision as a whole, binocular vision giving results inferior, both in point of frequency and time consumed, to those obtained monocularly with the better eye.

However, if we take the mean of the two monocular results in these cases, this mean falls very definitely below the binocular result. This perhaps explains the discrepancy between the conclusions of Part I and this part of the report. If (as is to be assumed, almost as a fact) the observers in this work had unequal vision in the two eyes; and if they either did not know which was the better eye, or used both equally in the monocular work, the comparisons drawn would amount to comparison of the binocular result with the mean of the two hypothetical monocular results. The actual comparison of mean monocular with binocular results, made from the results of Part I of this report, would lead to differences in the same direction and of about the same order of magnitude as those found in this part.

(2) THE TWILIGHT TESTS.

The twilight results were obtained exactly as the foregoing, except that the experimental runs were conducted late in the day and while darkness was coming on. Each observer used one type of glass for the entire day's run, using the opposite type on the second day. On March 22nd the program began at 6 P.M., and on March 25th at 5.45 P.M. As soon as the more distant men (*A* to *H*) became difficult to see, as shown by the results, the nearer ones (*X, Y,* and *Z*) were furnished with special schedules, so that one or another of the latter were exposed every ninety seconds from then on. This change in program took place at 6.36 P.M. and 6.34½ P.M. on the respective days, the times being indicated in Table XIV by the horizontal lines drawn across the appropriate columns. Nine and fifteen minutes later, on the respective days, the last observations of any of these men were made, the darkness having become too profound in the interval for further observation, even at these short distances. It will be noticed from the table, however, that on March 22nd the failure of the daylight program took place somewhat before the time mentioned, at about 6.24 P.M., making the twilight interval for that day 21 minutes.

This fact serves to emphasize the rapidity with which the daylight fails, for while during the day there are enormous variations in the intensity of light, vision is affected less by these than it is by the presence or absence of shadows. Yet from the last moment that it was practicable to distinguish a man at (say) 1500 yards

Twilight Results.

March 22

Station	Monocular 24 Observers S	ew	ro	Binocular 24 Observers S	ew	ro	Difference S	ew	ro	Weighted Monocular S	Results Binocular S
D	15	7	9	19	2	12	4	5	3	18.8	23 8
B	0	0	0	0	0	0	0	0	0	0.0	0.0
E	0	0		1	0		1	0		0.0	3.9
H	6	0	0	4	0	0	−2	0	0	8.0	5.4
G	0	0	0	2	0	0	2	0	0	0.0	2.9
Z	23	7	7	23	7	13	0	0	6	27.1	27.1
D	24	−5	7	24	3	15	0	8	7	30.1	30.1
B	0	0	0	0	0	0	0	0	0	0 0	0.0
F	18	−6	12	17	0	10	−1	6	−2	22.5	21.2
G	0	0	0	0	0	0	0	0	0	0.0	0.0
Y	16	0	2	13	1	1	−3	1	−1	27 1	22.0
Z	2	0	0	2	0	0	0	0	0	3.0	3.0
X	19	4	4	17	2	2	−2	−2	−2	28.4	25.4
C	0	0	0	0	0	0	0	0	0	0.0	0.0
A	14	0	0	18	2	2	4	2	2	15.5	20.0
D	21	1	7	22	5	7	1	4	0	26.3	27.6
B	0	0	0	1	0	0	1	0	0	0.0	2.8
Z	1	0	0	0	0	0	−1	0	0	1.5	0.0
H	0	0	0	0	0	0	0	0	0	0.0	0.0
G	0	0	0	0	0	0	0	0	0	0.0	0.0
C	0	0	0	0	0	0	0	0	0	0.0	0.0
Y	13	0	0	12	0	0	−1	0	0	22.0	20.4
A	1	0	0	1	0	0	0	0	0	1.1	1.1
H	0	0	0	0	0	0	0	0	0	0.0	0.0
X	11	0	0	12	0	0	1	0	0	16.4	17.9
Z	3	0	0	4	0	0	1	0	0	3.5	4.7
X	3	0	0	5	0	0	2	0	0	4.5	7.5
Y	3	0	0	3	0	0	0	0	0	5.1	5.1
Z	2	0	0	3	0	0	1	0	0	2.4	3.5
Y	0	0	0	2	0	0	2	0	0	0.0	3.4
X	2	0	0	2	0	0	0	0	0	3.0	3.0

Time
5.51
.52½
.54
.55½
.57
.58½
6.00
.01½
.03
.04½
.06
.07½
.09
.10½
.12
.13½
6.15
.16½
.18
.19½
.21
.22½
.24
.25½
.27
.28½
6.30
.31½
.33
.34½
.36
"
.37½
"
.39
"
.40½
.42
"
.43½
.45
.46½
.48
.49½

March 25

Station	Monocular 23 Observers S	ew	ro	Binocular 23 Observers S	ew	ro	Difference S	ew	ro	Weighted Monocular S	Results Binocular S
D	12	4	8	10	7	7	−2	3	−1	15.0	12.5
G	8	3	2	8	0	2	0	−3	0	11.4	11.4
F	19	13	17	23	9	18	4	−4	1	23.8	28 8
B	1	0	0	1	0	0	0	0	0	2.8	2.8
D	21	14	18	22	12	20	1	−2	2	26.3	27.5
A	17	3	11	20	9	14	3	6	3	18.9	22.2
F	13	4	8	13	6	9	0	2	1	16.2	16.2
C	18	2	−4	21	3	−1	3	1	3	19.9	23.2
X	18	2	2	21	3	3	3	1	1	20.9	31.4
D	21	4	16	23	16	22	2	12	6	26 3	28.8
I	17	4	4	17	4	6	0	0	2	28.8	28 8
G	11	−2	2	12	4	6	1	6	4	15.7	17 1
H	20	1	7	19	10	11	−1	9	4	26 8	25 5
Z	3	1	1	7	0	0	4	−1	−1	4.5	10 5
B	3	0	0	2	0	0	−1	0	0	8 5	5.6
D	22	−2	10	22	3	17	0	5	7	27.6	27.6
X	22	0	0	19	0	2	−3	0	2	32.9	28.4
H	19	0	−1	21	10	6	3	10	7	25 5	28 2
Z	22	9	15	21	14	20	−1	5	5	25.9	24.7
Y	12	0	2	13	6	6	1	6	4	20 4	22 0
C	23	1	1	23	2	1	0	1	0	25.4	25.4
X	23	−4	6	20	7	11	−3	11	5	34.3	29.9
A	23	6	6	23	13	13	0	7	7	25.5	25.5
E	0		0	0		0	0		0	0.0	0.0
B	0	0	0	0	0	0	0	0	0	0.0	9.0
Z	22	0	2	22	0	6	0	0	4	25.9	25.9
A	18	0	4	20	−1	7	2	−1	3	20.0	22.2
Y	5	0	0	5	1	1	0	1	1	8.5	8.5
Z	5	0	0	8	0	0	3	0	0	7.5	12.0
X	14	0	0	14	0	2	0	0	2	20.9	20.9
Y	9	0	0	10	1	1	1	1	1	15.2	20.9
(E)	0	0	0	1	0	0	1	0	0		
X	17	0	0	11	−1	1	−6	−1	1	41.6	37.6
(F)	13	1	1	17	5	8	4	4	7		
X	15	1	1	18	1	1	3	0	0	25.1	32.3
(H)	2	0	0	4	0	0	2	0	0		
Z	21	0	0	20	3	3	−1	3	3	24.7	23.6
Y	14	0	0	14	0	0	0	0	0	24.8	24.8
(C)	1	0	0	1	0	0	0	0	0		
Y	4	0	0	6	0	0	2	0	0	6.8	10.2
X	3	0	0	5	0	0	2	0	0	4.5	7.5
Z	1	0	0	1	0	0	0	0	0	1.2	1.2
Z	0	0	0	0	0	0	0	0	0	0.0	0.0
Y	1	0	0	0	0	0	1	0	0	1.7	0.0

Explanation.

S—the number of observers who recorded seeing the man at the designated station.
ew—the number of observers who correctly recorded the direction of the action.
ro—the number of observers who correctly differentiated the action.
For explanation of "weighted results" see page 353.

there remained only twenty minutes or so during which a man could be distinguished at 400 to 600 yards. Consequently, the results, extending as they do over only these short periods of time, do not show anything that is on the whole conclusive. Results to be conclusive would have to extend over longer periods of time, as, for example, on clear nights at a definite phase of the moon, and would require a specially arranged program suited to the low visibility under such conditions, as will be evident on inspecting the parts of the table corresponding to the critical intervals.

Examination of these parts of the table shows that the man in the field was detected, in many cases, by only a very few, often by none, of the 24 or 23 observers represented in the column. The percentage was extremely low, and percentages falling very near to either 0 or 100 are not, as a rule, reliable for the purpose of drawing conclusions, especially when they fluctuate as these do.

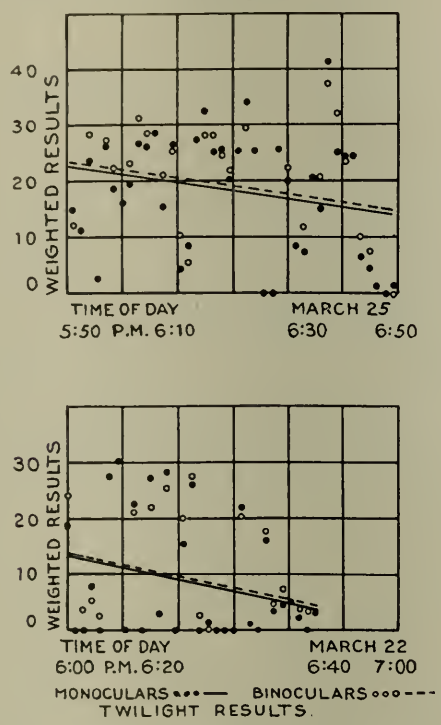
For reasons such as the above the results that were obtained March 22nd and 25th are given in Table XIV exactly as they were first summarized from the observers' original records. They represent in the aggregate 1¾ hours of work, of which, as was stated above, perhaps 35 minutes represent conditions pertinent to the point under investigation; while in the case of the daylight results just discussed the total time of work done by practically the same group of observers was 10 hours under favorable conditions.

The data were examined to see whether there was a noticeable difference in the behavior of the two types of glass as darkness approached. For this purpose only the numbers under *S* were employed, and each was assigned a weight, based upon the daylight observations, such that if the weighted number of times that the man at each station was seen were plotted as ordinates and the time of day as abscissæ, the resulting plot would approximate a horizontal straight line. The weight used for each station is the reciprocal of the average number of times, expressed in per cent., that the man was seen by both monoculars and binoculars on all four days of daylight observation. Those weights applied to data taken in waning light would naturally, when plotted, produce a line sloping downward as time progresses.

The weighted results are included in Table XIV and plotted

in Fig. 13. As was to be expected, the points scatter badly, so that any deduction based upon them should be substantiated by other facts before being considered final. The lines plotted were determined by the method of least squares on the assumption that

FIG 13.



the curve of decline is a straight line. The initial and final points of these lines yield the following information:

	March 22		March 25	
	Initial	Final	Initial	Final
Monocular	13.87	4.30	23.38	14.50
Binocular	13.51	3.67	22.46	13.70
Difference	0.36	0.63	0.92	0.80
$\frac{\text{Difference}}{\text{Monocular}} \times 100$	2.68	17.2	3.94	5.84

The last line of this table measures the advantage of the binocular over the monocular, and shows that this advantage increases as the light becomes dim; a result wholly in accord with the findings

of Part II of this report. From Table XIII the advantage, computed into comparable form, for the daylight results of Days II, III, and IV is $\frac{2.7}{78.4} \times 100 = 3.44$ per cent., a result quite in agreement with the two initial values just given, 2.68 and 3.94 per cent., considering the paucity and scattering of the data upon which the latter depend, as shown in Fig. 13.

In view of the inadequacy of the present data, little weight is to be given to the conclusions drawn therefrom. They in no way contradict the results of Part II of this report, but tend to confirm those results.

It is interesting to note, referring to Part II, that vision at the twilight intensity then used required an object 15.6 times as large (in terms of visual angle) as for daylight vision. We may roughly estimate a similar ratio for the two light-extremes involved in the work at Camp Meade.

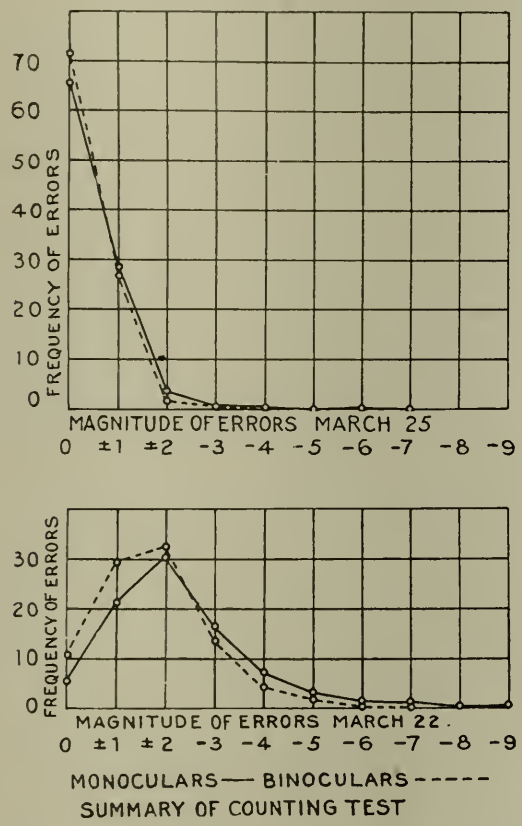
The average distance of *X*, *Y*, and *Z* is 487 yards. The average distance for the other eight stations is 1424 yards. Now, from the plots of the data in the earlier parts of this report it appears that a reduction in size of test object by one of the steps used, about 9 per cent., brings about a decrease of something like 25 per cent. in the frequency of observation. The frequency may be taken at 75 per cent. for the eight stations mentioned, and the estimate follows that in full daylight these men would be at the border of invisibility if removed to an average distance of 1424×1.09, or 1845 yards. That is, they would then be of about the same order of visibility as *X*, *Y*, and *Z* were at the close of the day's run. The ratio of the two visual angles would be 1/487 to 1/1845, or 3.8, as compared with 15.6, the similar figure derived from the laboratory results. That is to say, the illumination at the close of the day's twilight run in the open was such as to permit three times the visibility (measured in visual angle) obtained with the light previously used in the laboratory. This is, perhaps, another reason why the present results do not show a stronger twilight effect than they do in favor of the binocular.

(3) THE COUNTING TESTS.

The counting tests were conducted March 22nd, from 4.55 P.M. to 5.45 P.M., and March 25th, from 4.45 P.M. to 5.45 P.M., in each case immediately preceding the twilight test of that day. The program required all of the eleven men in the

field to be at a designated station, formed in an irregular line and concealed by crouching behind a slight rise of ground or, in the case of Station *H*, behind a brush concealment. At a word from their sergeant a prearranged variable number of them, from 7 to 11, rose to their full height, remained standing for 10 seconds and dropped out of sight again at a second command. The observers

FIG 14.



were informed in advance of the place to look, and were warned a few seconds before the men appeared.

This program involved Stations *B, D,* and *H* only. At each one there were ten exposures as described. In a short interval between the fifth and sixth the observers exchanged glasses, monocular for binocular, and continued with them until they re-exchanged after the fifth at the next station. Those who on

TABLE XV.

Counting Tests.

	Station *B*										Station *D*										Station *H*										Totals
	March 22, 1918																														
Men exposed	7	11	9	8	10	8	9	10	11	7	11	7	9	10	8	9	10	8	7	11	8	10	7	9	11	10	7	8	11	9	
	Monoculars																														
Correct counts	0	0	0	0	3	2	1	0	0	1	1	3	1	2	3	0	1	2	1	0	0	0	7	7	0	0	4	1	0	0	40
Errors +2	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
+1	..	..	1	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3	..	..	1	..	..	..	6
−1	1	..	3	3	10	16	2	2	5	23	1	4	4	4	2	7	8	4	1	3	3	2	5	6	4	..	8	6	..	10	147
−2	8	9	14	10	9	5	7	11	14	..	3	2	7	11	9	4	10	10	16	11	4	5	4	3	5	5	6	3	9	5	219
−3	5	7	3	7	..	..	8	8	5	..	1	4	3	3	4	5	2	6	5	5	5	4	3	1	4	8	2	4	4	4	120
−4	1	3	..	2	1	..	5	2	..	..	..	1	1	1	2	2	..	1	..	2	5	4	1	..	4	4	1	4	3	3	53
−5	1	..	..	1	..	..	..	1	..	..	..	..	2	2	2	3	..	..	..	2	1	..	..	..	1	..	..	3	4	..	23
−6	..	..	..	..	..	..	..	..	..	..	..	1	1	..	..	..	..	..	..	..	1	3	..	..	1	2	..	1	1	..	11
−7	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	1	1	..	..	..	..	1	..	1	..	2	..	..	1	1	9
−8	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	2
−9	..	1	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	1	..	4
Failures	8	4	2	1	1	..	1	..	..	..	17	9	4	..	2	2	2	1	1	1	5	5	4	3	3	3	2	2	1	1	85
Number of Observers	(24)					(24)					(24)					(24)					(24)					(24)					720
	Binoculars																														
Correct counts	0	0	3	1	2	4	2	1	2	1	1	3	4	3	5	4	6	3	5	3	0	0	9	10	0	0	5	1	0	0	78
Errors +1	..	..	..	..	1	..	1	..	..	..	..	..	..	..	..	..	..	1	1	..	..	..	1	3	..	..	1	..	..	..	9
−1	1	5	4	3	14	18	2	2	5	23	2	9	3	8	2	3	13	8	6	7	8	3	12	6	6	1	9	8	3	9	203
−2	12	13	16	16	7	1	5	12	13	..	2	2	6	8	10	9	3	6	9	10	9	12	2	2	10	11	4	7	11	7	235
−3	7	5	1	3	..	..	10	7	3	..	2	3	7	3	4	4	..	5	2	4	5	7	..	..	4	5	1	4	2	1	99
−4	2	..	..	1	..	..	3	1	..	..	1	..	2	1	..	1	1	..	..	..	1	1	..	2	2	4	..	1	2	5	31
−5	..	..	..	..	..	..	..	..	..	..	1	..	..	..	2	2	1	1	1	..	1	..	..	..	1	..	..	..	1	1	12
−6	..	..	..	..	..	..	..	..	1	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	3
−7	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	1	..	..	..	1	..	3
Failures	2	1	..	..	..	1	1	1	..	..	14	7	2	1	1	..	..	..	..	..	..	1	..	1	..	3	4	3	3	1	47
Number of Observers	(24)					(24)					(24)					(24)					(24)					(24)					720

March 25, 1918

Men exposed	7	11	8	10	9	10	11	8	7	9	8	7	9	10	11	11	8	9	7	10	10	11	7	8	10	10	7	11	9	9	
Monoculars																															
Correct counts	16	11	10	17	14	6	9	19	19	16	13	11	5	14	17	17	19	15	17	18	13	14	20	18	10	11	12	11	20	10	428
Errors +2	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
+1	..	1	1	3	2	1	1	1	2	1	5	3	1	1	..	..	2	1	1	2	1	..	1	..	1	1	1	..	3	3	40
−1	4	7	3	..	4	9	8	2	1	5	3	6	6	4	3	3	..	3	3	1	7	8	1	4	11	9	10	12	..	10	147
−2	..	1	..	..	..	1	4	..	..	..	2	2	6	3	3	1	..	..	..	..	1	..	..	..	..	2	..	..	..	..	26
−3	..	..	..	..	..	2	..	..	..	..	..	..	2	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	5
−4	..	..	..	..	..	1	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2
−5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0
−6	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	1
−7	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
Failures	..	..	..	..	..	1	..	..	..	..	..	..	3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4
Number of Observers	(20)					(22)					(23)					(21)					(22)					(23)					655
Binoculars																															
Correct counts	16	11	18	16	13	15	14	20	14	20	18	18	9	18	21	16	19	15	19	19	11	12	23	13	8	14	14	13	17	10	464
Errors +2	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
+1	..	1	2	2	4	1	..	..	4	..	2	2	..	..	..	2	2	1	1	2	2	..	..	..	3	2	1	..	3	3	40
−1	3	9	2	3	4	3	6	..	1	..	1	..	10	3	..	4	2	7	3	2	9	10	..	9	12	6	7	9	2	9	136
−2	1	..	..	1	1	1	..	..	1	..	..	..	..	..	..	1	..	..	..	..	1	1	..	1	..	..	..	..	..	..	9
−3	..	..	..	..	..	..	..	..	..	..	..	..	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2
Failures	2	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3
Number of Observers	(22)					(20)					(21)					(23)					(23)					(22)					655

the first day began with one type of glass began on the second day with the other.

The results are summarized in Table XV. In some cases the number was overcounted by 1, rarely by 2. Such cases are indicated in the table, but in the plot (Fig. 14) they are classed with the misses, irrespective of algebraic sign.

On the first day visibility was low on account of haze. This circumstance, coupled with the inexperience of the observers in this particular problem, made a characteristic difference in the outcome. It will be noted that the correct counts are few, 10.8 per cent. and 5.6 per cent. of the total with binoculars and monoculars, respectively, while on the second day the corresponding results are large, 70.8 per cent. and 65.3 per cent. In other words, most of the results of the first day involve errors. The upper plot will show, however, that apart from a 5.3 per cent. advantage in correct counts the binocular has to its advantage a lower number of large errors. Unless this were pointed out, the plot might be misleading, since it shows a conspicuously larger number of small errors for the binocular. This is simply the natural effect of the other circumstance. The binocular counts deviate less from correctness than the monocular. This is brought out by the following taken from Table XV:

	March 22		March 25	
	Monoc.	Binoc.	Monoc.	Binoc.
Experiments	720	720	655	655
Correct answers	40	78	428	464
Failures	85	47	4	3
Miscounts	595	595	223	188
Aggregate error in miscounts	1,461	1,202	277	202

The "aggregate error" does not here include the errors implied in the "failures," which are listed in the line above "miscounts."

The following weather notes are to be considered in connection with the above:

March 22nd, 4.55 P.M.—Light failing, fairly dense haze. 5.15 P.M. to 5.30 P.M.—Sun, well up in the sky, appeared red, not orange, and was on the point of going behind a cloud bank. 5.31 P.M. to 5.35 P.M.—Haze very deep and hard to penetrate with glasses.

March 25th.—Clear, except for occasional blowing sand. High wind, W. by NW., very cold, stiffening fingers. Very good seeing.

(4) THE TIMING TESTS.

In all of the preceding work the original group of officers, with such absences and substitutions as were unavoidable, acted as observers. In the timing work, about to be described, the observers were the group of men who had previously acted as visual objects in the field. These were ten privates and one first sergeant. The last, and seven others were men of some academic training, awaiting the opening of the Ordnance School; the other three, and one extra man on the second day, were privates detailed from the ranks of the Ordnance Company for this work. They were, on the whole, especially the first eight, men of intelligence and ambition. The work was done in the forenoons of March 22nd and 23rd.

On the first of these days the weather was warm and the air somewhat hazy. On March 23rd it was cold and exceptionally clear, with a tendency for the fingers to stiffen and so delay the observer.

In the test with the binocular the subject started with the glass in its case and the lid fastened. In the monocular tests the glass was initially in his breast pocket with the flap buttoned. Before the test was begun each observer adjusted his glass, including in the case of the binocular the clamping of the stop for limiting the interpupillary distance, and placed it in his pocket or in its case without disturbing the adjustments more than necessary. The test object consisted of two short, parallel black strips, ½ by 1½ inches, separated by an interval of ½ inch, and placed in the centre of a square white board, which was held by one of the men with the bars vertical or horizontal, according to a predetermined chance schedule, and at such a distance that the direction of the bars was not to be distinguished without the aid of the glass. This distance was about 160 yards.

At a given signal the subject started to get out the glass and as soon as he was able to see the object he announced the direction of the bars. Two stop-watches were used. One was started at the initial signal, the second when the subject had the glass at his eye, and both were stopped the instant he announced the position of the object. If he fumbled the glass, as happened especially on the second (cold) day, the experiment was thrown out and repeated; the same was done if, as occasionally happened, he announced the wrong position of the test object.

As the experiments were conducted there were two results from each. The watch first started gave the whole time required to get out the glass and to get good vision of the object; the second gave the time to get good vision from the instant the glass was in position at the eye or eyes. This last, for want of a better name, is here designated the "pick-up" time. The difference between the two will be the delay in getting the glass from its carrying-place to the eye. The results follow:

	March 22, 1918		
	Whole time	Delay	Pick-up
Binocular	6.87 ± 0.20	(4.25 ± 0.22)	2.62 ± 0.09
Monocular	5.53 ± 0.24	(2.59 ± 0.29)	2.94 ± 0.17
Difference	1.34 ± 0.31	1.96 ± 0.36	−0.32 ± 0.19
	March 23, 1918		
Binocular	6.94 ± 0.24	(4.60 ± 0.25)	2.34 ± 0.08
Monocular	5.85 ± 0.20	(3.07 ± 0.23)	2.78 ± 0.12
Difference	1.09 ± 0.31	1.53 ± 0.34	−0.44 ± 0.14

In the first day's work the figures are each the result of 22 experiments, in the second 24. The probable errors are added.

It will be seen that the delay is greater for the binocular by about 1.5 to 2.0 seconds, with a very small degree of uncertainty. These differences, of course, apply to the conditions of the experiment—the binocular carried in its case, slung over the shoulder with the lid fastened, and the monocular in the buttoned breast pocket. It is to be added that the binocular cases were new, and consequently stiffer and harder to handle than in average practice.

The difference in the pick-up time is in favor of the binocular. It is not large, but its probable error is sufficiently small to make it appear far more like a true experimental result than like an accident. The possibility remains, nevertheless, that this difference might disappear with adequate practice. Against this must be placed the fact that the difference is here greater on the second day than on the first. If we exclude the results of the twelfth man who came to this experiment for the first time on the second day, we get for the pick-up times: Binocular, 2.30 seconds; monoc-

ular, 2.83 seconds; difference in favor of the binocular, 0.53 seconds. As far as can be said from these results, then, this difference grows with practice rather than the contrary.

(5) OPINIONS OF THE OFFICER-OBSERVERS.

At the close of the last day's work of the officers who acted as observers in the first three tests detailed here, they were asked to state their personal preference as to the type of glass and to give their reasons for the choice.

Expressions were obtained in this way from 43 men, all of whom but one chose the binocular. The reasons stated were analyzed as follows:

GROUP I. Statements made as favoring the binocular:		
1. "Easier on the eyes" unqualified	20	*HS*
"For lengthy observation" ..... 3 "Trouble with open eye" 2	5	*S*
2. "Objects can be seen more 'clearly,' 'distinctly,' or 'with better detail'"	17	*CS*
3. "Movements more clearly defined"	2	*CS*
4. Superior in "blurry lights," on "dark days" or "in twilight"	4	*CS*
5. Easier to "pick up" an object	6	*CS*
6. "Better for close-up work" and "Better view of landscape"	2	*CS*
7. "Can change from point to point quicker"	1	*S*
8. Easier to get "steady vision," "hold steady" or "hold on object"	8	*S*
9. "Quicker adjustment"	2	*Q*
10. "Better illumination"	2	*PQ*
11. "Field of view larger"	9	*X*
12. "Brings objects nearer," "image larger" or "more powerful"	3	*X*
13. "Natural consequence that a person can see better with two eyes"	1	*P*
14. "Believe I can do better work"	2	*S*
15. "Blurring with monocular"	1	*S*
Total	85	85
GROUP II. Statements made as favoring the monocular:		
1. "Better on monocular with practice"	3	*S*
2. "No reason why it could not be used with success after I get used to it" or "for all but the finest work"	6	*S*
3. "Quicker pick-up"	1	*S*

4. "Lightness (and cost)"	1	S	
5. "Adjustment quicker and simpler"	2	S	
6. "Easier to handle"	1	S	
Total	14		14
GROUP III. Statements favoring neither glass:			
1. Seeing the same with both	8	S	
Total	8		8
Grand Total			107

The opinion of the writers as to the validity of these reasons is indicated by the letters following the numbers attached to each sub-group above, the key to these following:

C – Confirmed by the conclusions of this report or other facts.
H – Possibly hearsay.
P – Prejudgment.
Q – Question as to meaning of statement.
S – Statement of man's opinion as asked for.
X – Contrary to physical facts.

While there are 85 points, out of a total of 107, expressed in favor of the binocular, it is noteworthy that the statements in favor of the monocular and the indifferent statements are not subject to such dubious criticisms as are here symbolized by the letters *H*, *P*, *Q*, and *X*.

While it cannot be denied that an expression in favor, say, of the binocular, however clumsily and erroneously stated, might be motivated at bottom by the author's actual experience with the instrument, yet the common tendency is strong to read into that experience a mass of ostensibly related material—opinions heard which may or may not be well founded, and which may in either case be the basis of prejudgment; inferences from real or supposed facts otherwise known, and so on. For example, near the close of the work on one of the twilight runs, one of the men in the distant field stopped, on his way in, to talk with the man at *B*. While there he struck a match. While a number of the observers stated that at a certain minute "*B* lit a cigarette," there was but one who reported exactly what he saw, which was "a light at *B*."

The absence of questionable matter among the expressions in Groups II and III, and its presence in Group I above, would indicate that there does not exist any body of preconception in favor

of the monocular, while in favor of the binocular such preconception does exist. The exact results of this report bear out the opinions in their main tendency; nevertheless, it is clear that opinions not so supported can be credited only with the greatest caution. Otherwise, of course, the present work would not have been undertaken.

SUMMARY OF CONCLUSIONS.

(1) In daylight under various weather conditions 7174 experiments were conducted in the course of four days with binocular glasses, and simultaneously an equal number with optically identical monoculars. The test objects were men, one at each of eleven points in the field, their distances being various, from 410 to 1850 yards.

Out of the 7174 possible cases the men were detected in 5047 cases with the binoculars and in 4726 with the monoculars. The difference is 321, which is 4.5 per cent. of the total or 6.8 per cent. of the number observed with the monoculars.

One man at 1850 yards, walking just within a wood, was seen with the binocular 211 times, with the monocular 141, out of 684 posibilities in each case. The difference is 70, which is 10.2 per cent. of the total, or 49.7 per cent. of the monocular number.

The other men, at 410 to 1800 yards, were seen in 74.70 and 70.93 per cent. of 6490 cases with the binocular and monocular, respectively. The difference is 3.8 per cent. of the total, or 5.3 per cent. of the monocular result.

(2) The ability correctly to discriminate posture, once the man is localized in the field, is based on the number of times he is seen at all. It is different, according to the criterion of discrimination used.

For the detection of the fact, once the man is seen, that he is either aiming a rifle or extending an arm, the figures show: Monocular, 45.55 per cent.; binocular, 53.45 per cent.; difference, 7.9 per cent. of total men observed, or 17.3 per cent. of monocular result.

For correct discrimination between aiming a rifle and extending an arm, the corresponding figures are: Monocular, 36.34 per cent.; binocular, 45.18 per cent.; difference, 8.84 per cent., or 24.3 per cent. of the monocular result.

(3) How these differences will be affected by practice is indi-

cated in the results—the differences under (1), last paragraph of this summary are largest for the first day of work. Excluding the first day's work of each observer, the differences are 2.7 per cent. and 3.45 per cent., as against the differences 3.8 per cent. and 5.3 per cent. there stated for the four days. After the first day there is possibly still a tendency for the difference to diminish.

On the other hand, the detection and discrimination of posture improves no faster with the monocular than with the binocular as practice goes on; the difference tends to increase rather than to diminish.

(4) Similarly planned experiments carried out at the end of the day in the failing light showed slight increase in these differences as the light wanes. More abundant experiments would be necessary to settle this point conclusively, but the ones at hand tend to confirm the conclusions of Part II of this report as to the advantage of the binocular in light of twilight intensity.

(5) In counting groups of men, from 7 to 11 in number at distances of 1190 to 1800 yards, as compared with the monocular, the binocular showed more correct counts, by 5.2 per cent. to 5.5 per cent. of the total experiments; fewer total failures (by 44.7 per cent. of the monocular failures on one hazy day); and a smaller aggregate error in the remaining counts, by 17.7 per cent. and 27.1 per cent. of the aggregate monocular error for the two days, respectively.

(6) The differences in favor of the binocular, so far summarized, may be due in part to an inequality of the acuteness of vision in the two eyes, in that with the monocular the poorer eye is used alone a part of the time, while with the binocular the good eye is always at work.

(7) Forty-six experiments with each type of glass showed that 1.5 to 2.0 seconds more were consumed in the delay incidental to getting the binocular to the eyes from its carrying-place than were similarly required to get the monocular into action. On the other hand, the binocular, once at the eyes, enabled the user to report on an easily visible test object in 0.32 to 0.44 seconds less time than the monocular. The corresponding times themselves (delay and "pick-up" time), averaged for both glasses, were 3.6 and 2.7 seconds, respectively.

(8) Of the opinions of 43 observers who took part in the bulk of this work, all but 1 were in favor of the binocular. Of the

reasons, in detail, given for the choice, 85 were in favor of the binocular; 14 points of favor were at least admitted for the monocular, and 8 statements were made to the effect that the two afforded equally good vision. Evidence of preconception was abundant in the reasons stated for preferring the binocular and not elsewhere.

PART IV.

SUMMARY AND CONCLUSIONS.

IT remains to discuss the bearings of this work upon the practical question of field-glasses for military use.

A. The fundamental points in physiological optics upon which the problem rests have been discussed in the introduction. They are, as far as can be formulated:

(1) The question of visual acuity;

(2) The perception of brightness (and possibly color) difference;

(3) The twilight effect, *i.e.*, the modifications of these that may be encountered in dim light;

(4) The stereoscopic effect.

B. Aside from these, certain practical considerations enter the problem, some of which, at least, are less easily susceptible of experimental measurement:

(1) The cost and time of production and of maintaining the glass in usable condition; the ease of carrying, etc.;

(2) The comfort, convenience, freedom from fatigue and eye-strain in the use of the glass;

(3) The speed of application and use in the field.

A (1) Field tests with a limited number of observers (Part I of this report) showed, with equal mechanical convenience of using the glass, that the binocular use of the glass at best yielded no better results than monocular use in connection with the observer's better eye. The field tests of Part III do not confirm this, but it must be said that it is an unknown factor whether or not the observers in the latter case invariably used the better eye. Presumably they did not. And further, the mechanical convenience of using the glasses, monocular and binocular, in the latter case was not equalized. In addition, there was a decided difference in the character of the test objects used in Parts I and

III; in the former the object was of minimal size and maximal contrast, while in the latter the size of the objects placed them well above the threshold, but the brightness difference and also the color contrast were, as a rule, small.

(2) Laboratory work (without glasses) has shown that the perception of small brightness differences, *e.g.*, faint shadows, is more acute with two eyes than with one. Again, when the test object is the faintest luminous patch visible in the dark, it is found, when the subject has remained in the dark for some time, that the patch to be seen with one eye must be nearly twice as bright as the same surface just binocularly visible.

(3) The twilight modification of vision, with respect to visual acuity, occurred in the Laboratory (Part II) in the sense of better vision for the binocular, other conditions equalized. The results of the practical test confirm this for the conditions of the test, or at least they wholly fail to contradict it in any way.

(4) The stereoscopic effect plays a distinct, perhaps very important, part in ordinary vision in localizing objects as to distance. Yet it hardly appears that it is of prime importance from the military standpoint. In one case (Part III of the report) the test object at Station *D* was seen against a background much more remote, and afforded a very marked stereoscopic effect. The average results for the experiments on this station, and, for comparison, the averages for all stations from Table XIII are given here:

D, from totals, Table XI or XII

	S	*cw*	*ro*
Binocular	81.7	82.8	71.0
Monocular	78.0	74.5	60.5
Difference	3.7	8.3	10.5

D, weighted as finals, Table XIII

	S	*cw*	*ro*
Binocular	81.06 ± 0.08	81.34 ± 0.31	69.77 ± 0.53
Monocular	77.29 ± 0.01	72.53 ± 0.34	58.18 ± 0.22
Difference	3.77	8.81	11.59

All stations, as in Table XIII

	S	*cw*	*ro*
Binocular	74.70 ± 0.06	53.45 ± 0.05	45.18 ± 0.17
Monocular	70.93 ± 0.07	45.55 ± 0.14	36.34 ± 0.07
Difference	3.77	7.90	8.84

The first figures are the percentages derived from the total numbers under *D*, alike in Tables XI and XII. The second set are the averages of the daily percentages, weighted exactly as the values for all stations, Table XIII. For comparison the final averages for all stations (Table XIII) are here repeated.

It will be seen that the values for *D*, however treated, show the same divergence from the values for all stations. The *S*'s are practically the same, while under *cw* and *ro* the results for Station *D* are somewhat larger than the general averages. The binocular parallax at *D*—computed from the distances 1190 yards (*D*) and 1190 + 500 (background), taking the distance between the objectives from one of the binoculars used, set for 65 mm. pupillary distance, as actually measured, 4.9 inches or 0.136 yard, and finally, taking the magnification as 6—is 41.8 seconds of arc in the visual field. The station next to *D*, in point of the magnitude of effective parallax, is *A*. Here the distances are 1180 and 1180 + 67 yards, for the man and the background respectively, and the similarly computed parallax is 7.58 seconds. This last is very near to the lowest limit ever assigned as sufficient for a judgment of depth and agrees well with the informal note on Station *A*: "Not much stereoscopic effect," while the parallax at *D* is abundant. The conclusion would seem to be that the stereoscopic effect is a distinct advantage for binocular discrimination; but at the same time it must also be emphasized that, judging from the data just presented, the advantage of the binoculars is almost certainly due largely to other factors that have not yet received sufficient study in isolation, such as the comparative discrimination of small brightness differences, the detection of motion, and in general the part played by the peripheral retina.

In connection with the work done at Camp Meade, it is to be borne in mind that the differences between the monocular and the binocular results are not, in point of magnitude, of sweeping moment. At the maximum the difference amounts to something not over 12 per cent. of the total experiments. If we take it that 25 per cent. difference in frequency corresponds to 9 per cent. difference in size, the size difference equivalent to 12 per cent. frequency-difference is a trifle less than 4.5 per cent. It is then a safe theoretical conclusion that an increase of 4.5 per cent. in magnification (6.27 instead of 6.00) would offset the relative disadvantage of the monocular in the most unfavorable case. What

has just been said has reference to discrimination, under the headings *ew* and *ro* of Part III of the report. In regard to the effect of practice on these particular modes of vision the results seem to show, as far as they go, that the equalization of practice, up to the fourth and fifth days with the monocular, tends rather to increase than to diminish the difference. How far this would ultimately go remains undetermined.

B. As far as the cost and speed of production, and lightness, are concerned, the advantage is overwhelmingly in favor of the monocular. Perhaps under this general head is the place to mention again the difference of 1.5 to 2.0 seconds found in the time required to get the glass from its carrying-place to the eyes. On the other hand, the comfort of use, involving the relative freedom from eye-strain or fatigue in other respects, would play a part in determining the results of the tests; and it also figures in the opinions of the observers. The results of Part III of the report, under the head *S*, depend upon the number of times a given test object was seen, as compared with the total number of times it might have been seen. This depends obviously, on how continuously and thoroughly the individual observer watches the field. As a matter of course, the effectiveness of his vigilance will be influenced by such considerations as those just mentioned. The fraction of the whole time that he has the glass at his eyes will be reduced by the physical inconvenience of holding the glass in position and by the demands of his eyes and the rest of his body for relief from fatigue. These, again, will tend to diminish by habituation to any particular requirement. With regard to the results under *S*, it appears possible that the binocular-monocular difference actually did diminish in this way to some extent, as practice continued.

This difference itself is in harmony with the difference in the time of "picking up" an object, treated in the fifth section of Part III of the report. The difference was, on the average, something like 0.4 seconds in favor of the binocular, and the differences under *S* are no doubt simply another expression of the same underlying fact.

In the foregoing it has been shown that in the hands of not very highly experienced observers the binocular performs slightly better than the monocular, and that the difference in performance can, for 6-power glasses, be expressed as an effective difference in

magnification of about 4.5 per cent.; *i.e.*, a monocular of magnification 6.27 would show the same performance as a binocular of magnification 6.00. This difference of magnification is evidently not regarded by military authorities as of paramount importance, for 6-power glasses were adopted as standard even though tests on binoculars carried on for two years at Ft. Sill, Oklahoma, clearly indicated a magnification of 8 as the optimum for field artillery work. The adoption of the 6-power glass was presumably the result of a compromise between optical and other considerations. Since the behavior of the two types of glasses is not very different, and since the non-optical factors are largely in favor of the monocular, it appears that in many phases of military work, monoculars of the proper magnification can be used to advantage.

The writers wish to acknowledge the courtesy of the Mayfield Country Club in according them the privilege of the grounds for the purpose of the work discussed in Part I, the generosity of the Warner & Swasey Company for the loan of the two terrestrial telescopes used in Parts I and III, the hearty coöperation of all members of the Board to Test Snipers' Equipment in the work reported in Part III, and the services of Mr. George Hathaway and Mr. Stanley Seidman as observers and technical assistants in Parts I and II, respectively.

NELA RESEARCH LABORATORY,
CLEVELAND, OHIO.
August, 1919.

Experiments with Soy-bean Meal as a Substitute in the Army Ration are described by Capt. ARTHUR W. DOX in the *Proceedings of the Iowa Academy of Science*, 1918, xxv, 517–519. Soy-bean meal and soy-bean flour are by-products. The oil is pressed from the soy beans and the press cake is ground and sifted. The flour and meal used in the experiments contained 6.5 per cent. moisture, 44.1 per cent. protein, 3.3 per cent. fat, 5.9 per cent. crude fibre, and 35.5 per cent. carbohydrates. The experiments were conducted under the auspices of the Food Division, Sanitary Corps of the United States Army at Camp Travis, San Antonio, Texas, on messes of both officers and enlisted men; each mess included from 100 to 200 soldiers. The army ration prescribes 18 ounces of wheat flour, part of which may be replaced by other cereals. Soy-bean meal was used in soups; one and one-half ounces of the meal and one pint of boiling water was the proper ratio; they were boiled for five minutes, then the other ingredients

were added. The soup was not very palatable without proper seasoning. With seasoning a very palatable dish was prepared. For bread a mixture of 80 per cent. wheat flour and 20 per cent. soy-bean flour was used. The product was darker in color than wheat bread, but was excellent in flavor; the loaves did not attain the usual height. When more than 20 per cent. soy-bean flour was used, the loaves tended to become soggy; probably 10 per cent. would yield the best results. Unlike bran, admixture of soy-bean flour does not decrease the nutritive value of the bread, for soy-bean flour contains a high per cent. of protein or nitrogenous food, and this protein is of high quality and 96 per cent. digestible. For the same reasons soy-bean flour is preferable to corn meal.

J. S. H.

At the International Hydrographic Conference held in London in the summer of 1919, twenty-three countries were represented. The purpose was to compare and study the methods used in the several countries in order to determine the best among them and to standardize the hydrographic publications of all countries as far as possible. In the "Light Lists" now are included "wireless direction-finding stations" and "sound-ranging signal stations." It was recommended that all countries adopt "time zones" at sea, as Great Britain, France, and Italy have already done. A committee of which Rear Admiral Simpson, United States Navy, is a member is to present to the various governments the arguments for the establishment of an International Hydrographic Bureau.

G. F. S.

A Positive Ray Spectrograph. F. W. ASTON. (*Phil. Mag.*, December, 1919.)—After the positive rays have passed the cathode they traverse two very narrow slits. The resulting ribbon of rays is then spread out into an electric spectrum upon passing through a static field between two parallel plates. A part of the spectrum is allowed to traverse a diaphragm and subsequently a magnetic field between the parallel pole pieces of an electromagnet. This magnetic field deflects the rays in a direction opposite to that in which they were bent by the electric field. Rays which have the same relation of mass to charge now are brought to a focus and can be photographed. Preliminary tests indicate that the instrument gives clearly defined foci and leads the experimenter to hope that it may be used to determine whether neon is an element or an isotopic mixture.

"To make slits with beautifully parallel sides to almost any degree of fineness, .01 mm. being easily obtainable," Mr. Aston bores a hole in an aluminum cylinder and then flattens the hole out by crushing the cylinder.

G. F. S.

THE COLORIMETRY OF NEARLY-WHITE SURFACES.*

BY

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If from an assortment of papers, we had picked out the sheets which appealed to us as being white, we would be satisfied with our choice until we laid the sheets side by side. By comparison, some would be yellowish, others bluish, etc., and it would be difficult, if not impossible, to decide upon one sheet that was truly white. Problems of this character are continually arising in the paper, paint and textile industries. Up to the present time it has been sought to regulate the uniformity of product by establishing a series of standard examples which define the limits of tolerance. Leaving out of consideration the question of reproducibility, the principal objection to be urged against this mode of procedure is that the standards themselves are subject to change with time. To be sure, this difficulty has long been recognized and numerous attempts have been made to apply the methods of monochromatic and trichromatic colorimetry. However, these attempts have been unsuccessful because of the fact that the departure from white is usually so very slight that accurate measurements of this departure are out of the question. In the instrument to be described, the departure is much accentuated and is thus made amenable to accurate measurement.

Before taking up a description of the apparatus, it may not be out of place to discuss the term "white." According to Nutting [1]: "White is difficult to define and its definition is more or less arbitrary. Subjectively, white is that color in comparison with which any other color appears tinted. Objectively, the light of the midday sun [2] (blue sky light excluded), reflected from a non-selective surface, is white. White can be defined in physical

* Communicated by the Author.

[1] Nutting: "Outlines of Applied Optics" (p. 154), Blakiston.

[2] At present opinions differ as to the choice of a standard source of white light. Whether it is to be the midday sun, average daylight, or the visible radiations of a black body of known temperature, the action of some national or international body is urgently desired.

units only through its spectral energy curve." In speaking of a surface as yellow or blue, it is tacitly assumed that white light is incident on the surface. If, therefore, a body reflects selectively, it is to be called "colored," whereas, if it reflects non-selectively, it is to be called "white." According to this nomenclature it is entirely proper to speak of one surface as being "brighter" than another or "departing more from white." The term "whiter than" may not be used, because the two concepts (1) increase in brightness and (2) decrease in departure from white (saturation) are both involved.

The present discussion deals with surfaces of great brightness and small departure from white. In order to accentuate this departure, the method of multiple reflections was applied. If white light be allowed to fall on the surface that is slightly greenish, it is obvious that the diffusely reflected light will contain an excess of green. If now this light be allowed to fall on a second surface, identical with the first, the light reflected will be, relatively, still richer in green. By allowing similarly, a third and fourth reflection to take place, it is possible to accentuate the green tint very pronouncedly. If a surface be truly white, *i.e.*, non-selective, multiple reflections will affect only the intensity of the light—not its spectral distribution. As will be shown later, we have here an extremely sensitive test of selectivity. Anticipating the results to be presented it may be stated that of the many surfaces studied (papers, salt, sugar, zinc oxide, white lead, precipitated salts, etc.), not a single one has been found that does not depart noticeably from white.

Multiple reflections may be realized in a number of different arrangements, as is shown in Fig. 1. Here (*a*) represents a tube coated on the inside with the material to be tested (3 reflections); (*b*) represents two circular discs coated on the sides facing one another (3 reflections); (*c*) a hollow sphere with central disc (4 reflections). The condition sought in all cases is that no light leaving the surface after the first reflection shall illuminate directly that portion from which the light finally emerges. Clearly, the design (*d*) is faulty but (*e*) is good. While it is true that the accentuation of tint increases exponentially with the number of reflections, a limit is set because of the resultant decrease in intensity. Furthermore, preference must be given that design which lends itself most readily to the application of the surface

to be studied. Taking all of these elements into consideration the design (*b*) was finally chosen and incorporated in the colorimeter.

The degree of accentuation may be calculated with readiness by studying the change in brightness (coefficient of diffuse reflection) resultant upon the successive introduction of two different surfaces into the colorimeter. Let

I_0 = intensity of incident light.
I_1 = intensity of light after n reflections from material 1.
I_2 = intensity of light after n reflections from material 2.
R_1 = coefficient of diffuse reflection of material 1 (known).
R_2 = coefficient of diffuse reflection of material 2 (known).
n = number of reflections.
K = instrumental constant.

Then: $\frac{I_1}{I_2} = \frac{I_0 K R_1^n}{I_0 K R_2^n}$ or $\frac{I_1}{I_2} = \left(\frac{R_1}{R_2}\right)^n$

whence $n = \frac{\log \frac{I_1}{I_2}}{\log \frac{R_1}{R_2}}$

For a substance of unknown brightness R_3:

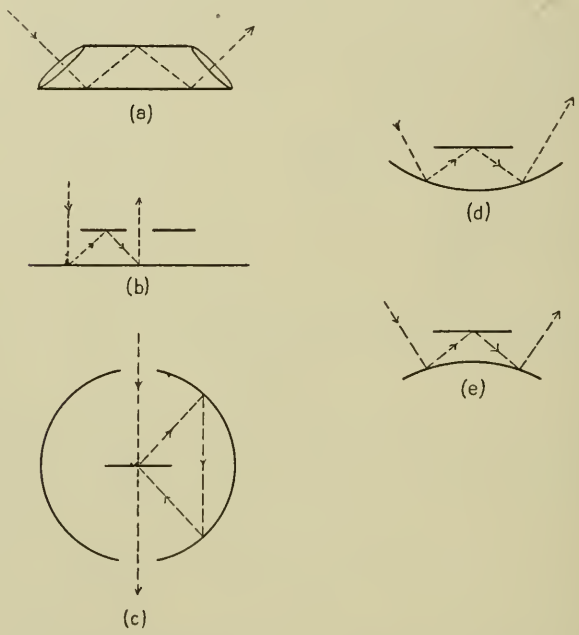
$$R_3 = R_1 \sqrt[n]{\frac{I_3}{I_1}}$$

Now R_1 and R_2 may be determined by means of a Nutting (absolute) reflectometer or by means of the usual methods of photometry, in which case use in made of a surface smoked with magnesium oxide, whose reflecting power has been determined (87 per cent.) and which serves as a standard of brightness. The intensities I_1 and I_2 are determined with the new colorimeter. The value of n is determined by the relative sizes of the colorimeter plates and of their separation. For separations of the order of the diameter of the upper disc $n = 3$ or slightly greater; as the separation decreases, n becomes larger. For the actual tests here recorded, the separation was such as to yield the value $n = 3.6$ while in a series of tests later on with a smaller separation $n = 4.2$. If we were dealing with specular reflection, n would necessarily have to be a whole number. However, we are dealing with diffuse reflection and, while n must equal at least 3, it may be considerably larger, due to the numerous reflections which take place. Since the human eye cannot detect differences in intensity less than 1 to 2 per cent. (Fechner's Law) it is clear that

the method of multiple reflections makes possible a discrimination between two surfaces whose brightness difference is, roughly, one-fourth of the above.

Considerations of a similar nature apply to the determination of the departure from white or "saturation," *i.e.*, if green light be in excess by 1 per cent. after a first reflection, the excess will be approximately 4 per cent. after multiple reflections have taken place. Considering the truly marvelous sensibility of the eye in

FIG. 1.

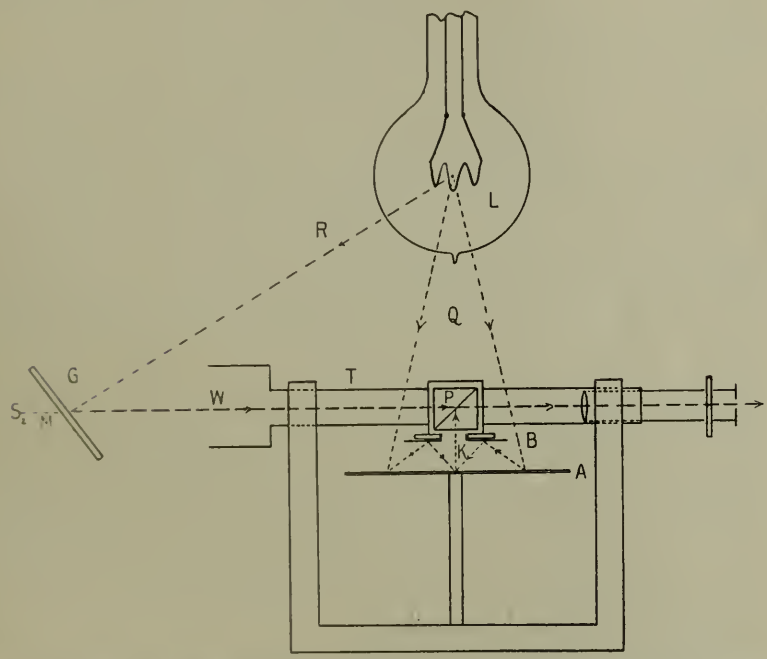


distinguishing color differences between two contiguous surfaces of large area, it would be rash to state that the new colorimeter is able to determine color differences between two surfaces which, under normal conditions, appear to be of the same brightness and tint. This much may be said, however: if the colorimetric analysis of the two surfaces is the same, the unaided eye may be able to distinguish a difference without being able to define the character of that difference.

The apparatus, as actually constructed, is shown in Fig. 2. Here L is a 100 watt Mazda C lamp which illuminates the outer

portion of the circular disc A whose upper surface is covered with the material to be studied. The light, diffusely reflected, illuminates the lower (coated) surface of the disc B, which, in turn, illuminates the central portion of the dic A. The light, after multiple reflections, passes upward through a central opening in B and is reflected horizontally by means of the photometer cube P. Another beam of light leading L is reflected from a disc of clear optical glass G, roughly ground on both sides. (Without going

FIG. 2.



into details it may be stated that the most painstaking tests have shown that such a plate reflects visible radiations non-selectively.) This light passes through the tube T and fills the upper half of the field of view of the photometer cube which has a horizontal line of demarcation. The intensity of this beam varies by rotating the disc G about a horizontal axis. A pointer, attached to the rod bearing disc G moves over a graduated scale and thus yields readings corresponding to definite positions of the plate G. Numerical values of intensities are obtained as a result of separate calibration involving the removal of plate A and the

admission of a beam of light K coming from a separate lamp (mounted on a photometer-bench) and illuminating a surface of MgO. This light reflected diffusely, is again deflected by a prism along the path K. So as not to complicate the drawing unduly, this calibrating device is not shown. The intensity of the light leaving G may be varied in the ratio 1 : 15. Whenever it becomes necessary to extend this range in either direction, a wire gauze, coated with soot, is introduced either at R or Q. Since the percentage transmission of the gauze may be regulated by choosing the appropriate ratio of width of mesh to diameter of wire, it is possible to take care of all possible cases.

The photometer tube is viewed through a simple eye-piece yielding a linear magnification of 2.5. Openings are provided in the eye-piece tube for the insertion of a piece of "daylight" glass which transforms the yellowish light from the tungsten lamp into "white" light. It must be admitted that the instrument is incomplete, in so far as character of "white" light is concerned. As previously mentioned in a foot-note, this matter is beyond the writer's control. Preliminary experiments have been carried out to realize a source of white light. Using solutions of colored inorganic salts in absorption cells, together with a tungsten lamp, burning at a known efficiency, it was possible to reproduce noonday sunlight very closely. This work will be taken up anew when the definition of white light shall have been established. In the preliminary experiments a piece of daylight glass was used and the tungsten lamp was burned at an efficiency of 0.8 watt per candle. Consequently the results to be presented later must be looked upon simply as illustrations of the types of problems which may be attacked.

In order to produce a colormatch, a beam of monochromatic light, emanating from the secondary slit S_2 of a monochromatic illuminator, is projected on the plate G and passes through it—thus, monochromatic light is superimposed on the white light from L. The intensity of the former is varied by means of a rheostat in series with the lamp illuminating the slit of the monochromatic illuminator. Color-matching is not a simple operation since three variables: (1) intensity of white light, (2) intensity of colored light, (3) wave-length of colored light have to be controlled. Proficiency is reached only after long experience.

If the surfaces A and B reflect very selectively it is difficult to

balance the markedly colored beam (K) against the white beam (W) and it will always be difficult to balance the monochromatic beam (M) against white light with the arrangement shown. Obviously a device involving "flicker" ought to be introduced to replace the simple eye-piece. While a design for such a flicker-photometer has been prepared, it was found possible to dispense with its use primarily because of the fact that the surfaces dealt with departed from white but slightly. The intensity of the monochromatic light is determined by the "method of differences," as will be shown presently.

Following the usual methods of monochromatic colorimetry, color characteristics of any surface (single reflection) are defined in terms of:

1. Brightness (B), coefficient of diffuse reflection.
2. Saturation (S), ratio of intensity of monochromatic light to total light required to produce a color-match.
3. Dominant Hue (λ), wave-length of monochromatic light.

Since the necessary mode of procedure for obtaining the brightness (B) has already been discussed it is only necessary to take up the matter of saturation (S).

Let

I_0 = intensity of white light required to balance light from surface under investigation (single reflection).

I_1 = intensity of white light necessary for color-match.

I_λ = intensity of colored light necessary for color-match.

Then $I_0 = I_1 + I_\lambda$ whence $I_\lambda = I_0 - I_1$

then $$S = \frac{I_\lambda}{I_1 + I_\lambda} = \frac{I_0 - I_1}{I_0}$$

According to this procedure, I_λ need not be measured, hence the introduction of a flicker-photometer becomes unnecessary.

The value of λ is obtained from the calibration curve of the monochromatic illuminator. If, instead of a single reflection, n reflections are realized, then the saturation is accentuated and it is necessary to extract the *nth* root of the apparent saturation so as to reduce the measurement of the conditions under which the surface is normally viewed, *i.e.*, a first reflection.

Whenever the departure from white is marked, *i.e.*, when the true saturation is 5 per cent. or more, readings are easily reproducible. Intensity measurements rarely differ by more than 1 per

cent. and the dominant hue can be fixed to within 1 to 1.5$\mu\mu$. However, when saturation values are small (less than 0.7 per cent.) measurements become increasingly difficult—particularly in fixation of the wave-length of the dominant hue.

The following table contains data on the color characteristics of a number of nearly-white substances:

Substance	Brightness	Saturation	Dominant hue λ in $\mu\mu$	Remarks
	Per Cent.	*Per Cent.*		
Magnesium Oxide....	85	0.2	486 Blue	Fumes from burning Mg.
Magnesium Carbonate	87	0.75	578 Yellow	Scrapings from commercial black—flattened with glass.
Paper.....	67	0.70	489 Blue	Single sheet linen paper (thin)
Paper.....	74	3.0	581 Yellow	Single sheet linen paper (heavy)
White lead.....	69	3.8	580 Yellow	Rubbed down with pale linseed oil—paste form
Zinc Oxide (pure).....	77	1.0	562 Green	Rubbed down with pale linseed oil—paste form
Zinc Oxide (leaded)...	68	7.1	583 Yellow	Rubbed down with pale linseed oil—paste form

All of these substances depart markedly from white. Even magnesium carbonate, which has been used frequently as a non-selective reflector in colorimetric investigations, is definitely yellowish.

In common with others, the writer found that much training and experience is necessary before reliable measurements, of the kind presented, may be obtained. Following the well-known practice, the procedure was simplified by eliminating measurements of saturation and dominant hue and instead, determining the brightness for blue, green and red light. Color-screens of dominant hue: 440$\mu\mu$ (blue), 550$\mu\mu$ (green) and 625$\mu\mu$ (red) were, in succession, placed before the eye-piece and the brightness for these three colors was determined. While this method lacks the scientific rigor of the former, it possesses marked advantages. First of all, no standard "white" light is required; (2) no color matching is necessary; (3) it serves admirably in establishing limits of tolerance, *i.e.*, selectively, for substances which are already nearly-white.

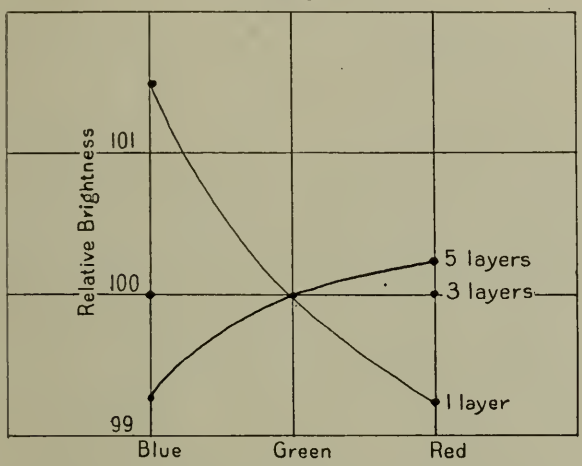
By means of this arrangement a detailed study of MgO, obtained by allowing the white smoke from burning magnesium ribbon to deposit on the colorimeter plates, was undertaken.

Altogether, five successive layers of MgO were deposited—measurements being taken after each deposit. The final thickness of layer was about 0.6 mm. The changes in selectivity of reflection are shown in the following curves: (See Fig. 3.)

While the color is decidedly bluish for one layer, it changes to yellow when five layers are employed. Curiously enough, the surface is truly "white" at three layers.

In conclusion it is to be stated that the advantages derived from multiple reflections need not be sacrificed when markedly colored surfaces are to be studied. The only difficulty here is to

FIG. 3.



get enough light for accurate measurements. A separate instrument is being developed to take care of this contingency.

Following is a summary of the preceding discussion:

1. Taking advantage of the circumstance that multiple reflections from similar surfaces accentuate selective reflection, a new colorimeter, adapted to the study of nearly-white surfaces, has been developed.
2. Measurements are presented to show that our usual standards of "white" ($MgCO_3$ and MgO) depart noticeably from this ideal.

JOHNS HOPKINS UNIVERSITY.
RESEARCH LABORATORY OF THE
NEW JERSEY ZINC COMPANY.
November 4, 1919.

Statistics on Sugar Consumption in the United States are given in the *Weekly News Letter of the U. S. Department of Agriculture* (vol. vii, No. 25, p. 3, January 21, 1920). The total consumption in 1919 amounted to over 9,000,000,000 pounds or 4,500,000 tons, while the normal domestic production is 1,000,000 tons. The average per capita consumption was 18 pounds in the year following the Civil War, and ranged from 24 to 50 pounds each year thereafter until 1890. The average yearly per capita consumption in each decade was:

1866–1875: 35 pounds.
1876–1885: 42 pounds.
1886–1895: 57 pounds.
1896–1905: 67 pounds.
1906–1914: 81 pounds.

Since 1914 each person has used, on the average, 85 pounds annually, and approximately 92 pounds during 1919. J. S. H.

Safety Devices in Tin-can Plant. (*Canadian Machinery,* through *Technical Review,* vol. v, 1919, 252.)—The power press used to be the most dangerous of ordinary machinery, except the circular saw. By introduction of various forms of guarding attachments, accidents have been greatly diminished. Dangerous overhead belts are guarded from below, spokes of fly-wheels are covered with metal disks. In making cans the lids are no longer fed into the machine by an operator, but from a tray on to a travelling feed-band, so that the operator is out of direct touch with the machine. In another series of machines the feeding table is fitted with a reciprocating movement, going forward under the punch for the stroke and coming back to the original position for the removal of punchings and the feeding of a new piece. A transparent guard in front of the punch enables the workman to watch the operation.

Another machine with which many accidents formerly occurred is the rotary cutter for slitting the sheet tin into strips. An iron guard is now placed in front of the knives for the full width of the machine, sloping down under the knives, leaving only a narrow opening for the introduction of the sheet.

These and numerous other safety devices which have been introduced have not only greatly diminished the number of injuries, but have increased output.

In this connection mention may be made of a special safety device used in one of the plants for making talking-machine records. In this work, a soft mass in the form of a flat plate about ten inches in diameter is pressed between two dies. The great danger is that the attendant may thoughtlessly place the hand between the dies. To prevent this a guard automatically moves in front of the machine, as soon as the dies begin to descend, and this will push the attendant's hand to one side in ample time to avoid crushing.

H. L.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

A PECULIAR TYPE OF INTERCRYSTALLINE BRITTLENESS OF COPPER.[1]

By Henry S. Rawdon and S. C. Langdon.

[ABSTRACT.]

When copper is heated in a molten bath of sodium chloride for the purpose of cleaning and softening, it has been noticed that the copper was embrittled. Under these conditions the copper is more or less in contact with iron or steel, either from a stirring rod, forceps for handling the piece or the pot used to contain the salt, and a "galvanic couple" with the copper as cathode would be formed.

Experiments were made with small rods of copper and mild steel which were made either anode or cathode in a bath of molten salt and with an e.m.f. of approximately 6 volts. The brittleness of the copper rods was compared with untreated material by bending the specimens back and forth with one end firmly clamped.

The copper rod which was an anode was as tough and soft as the original and required practically the same number of bends to cause it to fracture. The cathode copper was found to be very brittle.

Microscopic examination showed the anode copper to be perceptibly smoother on the surface than the original material; the structure was that of annealed copper. In the cathode copper rod the crystalline boundaries on the surface are well defined, and the intercrystalline boundaries for an appreciable depth within the metal are made wider.

The probable explanation of embrittlement of the copper when it is made the cathode is that an appreciable amount of metallic sodium is formed by the electrolysis which immediately alloys with the copper, the attack being selective towards the grain boundaries rather than forming an alloy layer of uniform thickness upon the outside.

* Communicated by the Director.

[1] Technologic Paper No. 158.

PHYSICAL TESTS OF MOTOR-TRUCK WHEELS.[2]

By C. P. Hoffman.

[ABSTRACT.]

TECHNOLOGIC Paper 150 relates to certain tests made for the military departments of the Government at the Bureau of Standards. A brief summary of this work is given below.

In designing Class B military truck it was found desirable to develop a metal wheel having the good qualities of all the wheels on the market. No comparative values were available, however, and there was no time for service tests. The Bureau of Standards was therefore called upon to make laboratory tests.

The wheels tested were made of cast steel, pressed steel, wrought iron and wood by various manufacturers. Each wheel was supported upon a shaft which fitted the bore of the hub and a radial compressive load was applied to the rim midway between two spokes by a bearing block which fitted the rim.

A "side thrust" test was also made by supporting on a similar shaft and applying a concentrated load on the rim in a direction parallel to the shaft.

Using the information obtained from these tests, a hollow spoke and rim cast wheel was designed for the Quartermaster's Department which was called the "Composite Wheel."

When tested, these proved satisfactory and were adopted for use on the Class B military truck.

The results of tests upon twenty-one wheels are given. The deformations of the wheels in the radial compression test were recorded for four points on the rim spaced 90 degrees apart. Load deformation graphs plotted from these data are given from which the proportional limit and elastic resiliences of the wheels at loads up to that limit are computed.

Similar data were obtained from the "side thrust" tests and graphs plotted. The proportional limit and elastic resiliences were obtained in the same way.

It is obvious that the strongest wheel is not necessarily the best for actual service. The elastic resilience of the wheel under low loads is also important as it measures the capacity of the

[2] Technologic Paper No. 150.

wheel to absorb shocks. This elastic resilience for unit weight of material served as the chief basis of comparison between different types of wheels.

A photograph and description is given for each wheel with the weight and a chemical analysis of the material for the metal wheels.

In designing a truck wheel, careful consideration should be given to several conflicting elements in order to obtain the best results. This paper gives experimental data which should serve as a guide in such work.

One of the cast steel wheels was tested in radial compression and the strain-gauge used to determine the actual deformation of the material in the wheel. Observations were made on the rim, on the spokes and on the hub.

The average modulus of elasticity was determined for specimens cut from the wheel and this value used in computing the stress at places where the deformation was observed.

From these data, graphs were plotted showing the stress in the wheel at forty-eight gauge lengths for loads on the wheel up to 60,000 pounds. Due to the short gauge length (2 inches) results of great precision were not to be expected but in this case the results were very satisfactory.

Stresses in wheel under load.—

Compressive stresses were found in all parts of the rim except the section between the spokes adjacent to the loading block. That section was subjected to tensile stresses by the behavior of the spokes. The only excessive stress in the hub was at the junction of the two spokes adjacent to the loading block where the tensile stress reached the proportional limit of the material when the applied load was 50,000 pounds.

The stresses in the spokes were all within the proportional limit of the material except for two gauge lines on one spoke adjacent to the hub. Possibly these were located at a thin section of the casting.

These strain-gauge results, the first of their kind so far as is known, should lead to the determination of the stress in wheels tested for investigational purposes. Only in this way can the most satisfactory distribution of the material be obtained. Such data allow the re-design of a wheel so as to avoid excessive stresses which cause failure in service tests.

INVESTIGATION OF THE COMPRESSIVE STRENGTH OF SPRUCE STRUTS OF RECTANGULAR CROSS-SECTION AND THE DERIVATION OF FORMULAS SUITABLE FOR USE IN AIRPLANE DESIGN.[9]

By James E. Boyd.

[ABSTRACT.]

TECHNOLOGIC Paper 152 describes certain tests of spruce, particularly with reference to suitability for use in airplane construction. The work relates chiefly to the derivation of formulas to guide the designer and engineer.

Compression tests were made on 58 square-end and 24 round-end spruce struts of uniform cross-section approximately 1.75 inches square. The length of the struts varied from 12.625 inches (slenderness ratio 25) to 126.25 inches (slenderness ratio 250). Complete measurements showing compression, lateral deflection and load up to the ultimate, were made on all the struts, the longer struts being tested to destruction. In addition, cross bend tests were made on representative specimens to determine the modulus of elasticity, resilience, and modulus of rupture. Complete data are given for three representative struts and summaries of the results on all.

These experimental results are compared with Rankine's formula, Euler's formula and the rational formula for eccentric loading. The constants were calculated from the experimental data.

Round-End Struts.—

For round-end struts the rational formula gives the best results over the whole range, but is inconvenient to use. Rankine's Formula:—

$$\frac{P}{A} = \frac{5200}{1 + \frac{L^2}{3000r^2}} \qquad (1)$$

for short struts (slenderness ratio <80) and Euler's Formula:—

$$\frac{P}{A} = \frac{16{,}000{,}000}{\left(\frac{L}{r}\right)^2} \qquad (2)$$

for slender struts (slenderness ratio >80) gave results within the experimental error.

[9] Technologic Paper No. 152.

Square-End Struts.—

For square-end struts accurately fitted to rigid supports Rankine's Formula:—

$$\frac{P}{A} = \frac{5200}{1 + \frac{L^2}{12{,}000r^2}} \tag{3}$$

gave results within the experimental error.

This condition is almost never realized in practice so that values between those given by (3) and (1) should be used in square-end construction, depending on the manner of fixing the ends. In particular, ordinary airplane pin connections should be considered as round ends, both in the plane of the pins and at right angles to it.

In the formula given above—

P = ultimate load in pounds.
A = cross-section area in square inches.
L = length in inches.
r = radius of gyration in inches.
$\frac{L}{r}$ = slenderness ratio.

For testing woods for use in struts, compression tests on slender round-end struts $\left(\frac{L}{r} = 200\right)$ with the use of Euler's formula gives an easy method of determining the modulus of elasticity, which agrees well with values obtained from cross-bend tests.

The results of this experimental work on spruce struts of uniform cross-section having shown the applicability to these struts of the rational formula for eccentric loading and its limiting case for central loading (Euler's formula), the analogous formulas for a certain type of tapered strut were developed.

In these struts the moment of inertia varies according to the law $I = Cx^2$; where "x" was the distance measured from some point beyond the end of the strut. Struts of this form approximate closely the tapered struts used in airplane construction.

The formulas for eccentric loading are complicated, but the results for central loading corresponding to Euler's formula are simple, and, by the aid of a graph, are easily applied.

A graph for this purpose is given and a number of approximate methods are discussed.

LOAD STRAIN GAUGE TEST OF 150-TON FLOATING CRANE FOR THE BUREAU OF YARDS AND DOCKS, U. S. NAVY DEPARTMENT.[1]

By Louis J. Larsen and Richard L. Templin.

[ABSTRACT.]

TECHNOLOGIC Paper 151 reports the tests of a floating crane which at present is of interest from an engineering point of view.

The fact that a floating crane failed under load on the Panama Canal made it desirable to test a 150-ton revolving floating crane built for use at the Navy Yard, Norfolk, Va. This structure is statically indeterminate and strain-gauge measurements were taken under load to determine the stress in the more important members.

This crane represents the most advanced type of revolving floating crane of large capacity. The jib is a tapering Pratt truss, hinged to the superstructure in the lower chord and connected to the luffing screws at the upper chord by suitable links. The length of the links and the location of the luffing screws are such that a nearly direct pull is exerted on the upper chord of the jib for all positions. The superstructure, exclusive of the jib, consists of two sub-divided triangular trusses rigidly connected by cross-bracing. The entire revolving load is transmitted by the triangular trusses to the pontoon through a pintle, the pintle being an inverted pyramidal-shaped member built up on four posts which transmits its load at the apex to a thrust bearing on the deck of the pontoon. The pintle is supported laterally on a tower consisting of six legs arranged in the form of a hexagon, the legs of the tower being carried through the deck to the framing of the pontoon. The tower is framed into the hull in such a manner as to make the pontoon act as a large girder in resisting the forces induced by a crane load. The pintle rotating within the tower makes it possible to revolve the superstructure with the live load to any position.

Readings were taken at various points of the deck to determine the magnitude, and, if possible, the position of the maximum stress in the upper deck plate; on the tower members to determine whether the tower acted as a unit; around the manhole in the tower legs to find the effect of such an opening; on the pintle to determine the magnitude of the stress in these members,

[1] Technologic Paper No. 151.

and on various members of the superstructure to determine the manner in which the loads were carried down to the pintle.

Gauge lines were placed on two opposite sides of every member tested, and where possible, on all four sides. Gauge lines were laid out on the deck of the pontoon for the purpose of determining the amount of stress developed in the plates of the pontoon deck and to check the computed locations of the maximum bending moments.

Strain-gauge readings were taken with a 10-inch Berry Strain-Guage, it being possible to read the change of length between the points of the instruments directly to the nearest 0.0002 inch, and by estimation to 0.00002 inch.

The material used for loading the crane consisted chiefly of armor plate and scrap iron of known weight. The loading was so arranged that each member on which measurements were taken, was subjected to the maximum possible range of stress.

The strain-gauge work done on this structure showed that all stresses on the various members were within safe limits.

The stresses in the deck were found to be low.

The maximum stresses in the outer edge of the tower legs are 17,000 pounds per square inch compression and 13,500 pounds per square inch tension.

The maximum stress in the pintle post is 18,000 pounds per square inch compression.

The stresses in the superstructure and in the luffing screws due to the load are not excessive.

CEMENTS FOR SPARK PLUGS.[5]

By Homer F. Staley.

[ABSTRACT.]

The use of cements for sealing electrodes into spark-plug porcelains has been found to be attended by serious difficulties in high temperature engines such as airplanes. Among these are: promotion of oxidation and destruction of the electrode wires by reactions taking place in the cement and between the cement and electrode wires; breaking of spark-plug porcelains caused by difference in coefficients of thermal expansion of electrode wires

[5] Technologic Paper No. 155.

and porcelain; and cracking of cement, with consequent gas leakage, due to the same cause. A cement composed of silicate of soda and raw kaolin has been found to give little trouble from chemical action. In order to avoid the difficulties attending the use of any form of cement, the use of a mechanical seal at the top of the porcelain has been tried with promising results.

AREA MEASUREMENT OF LEATHER.[6]

By Frederick J. Schlink.

[ABSTRACT.]

THIS paper deals with the investigation of area measuring machines used for integrating the area of leather hides and skins. The importance of the problem of area measurement in view of the enormous amount and value of leather handled annually on this basis ($450,000,000 in U. S. A.) is indicated. The principles of design involved in typical machines are set forth in detail and an analysis is made of the sources of the serious errors which commonly exist and of the means available for detecting and correcting them, including a complete regime for the determination of the performance of the machine tested with regard to both the accuarcy and consistency of its determinations. Numerical data illustrative of the various errors and performance characteristics of typical measuring machines are tabulated in detail.

HYDROGEN ION CONCENTRATION IN DRY CELLS.[7]

By H. D. Holler.

[ABSTRACT.]

THE potentials of electrodes consisting of mixtures of Acheson graphite with three different manganese ores and a chemically prepared oxide were measured in ammonium chloride solutions of different hydrogen ion concentrations. The potential of the electrodes containing the ores was found to be a logarithmic function of the hydrogen ion concentration, while the potential of electrodes containing the chemically prepared oxide was found to be independent of hydrogen ion concentration. The potential

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[6] Technologic Paper No. 153.

[7] Scientific Paper No. 364.

of the ores was found to decrease in acid solution and to increase in alkaline solutions. The relation found between the potential of the manganese dioxide electrode and hydrogen ion concentration, explains variations in open-circuit voltage of dry cells containing a given ore and also accounts for a portion, at least, of the polarization of dry cells on discharge.

THE METALLOGRAPHIC FEATURES REVEALED BY THE DEEP ETCHING OF STEEL.[8]

By Henry S. Rawdon and Samuel Epstein.

[ABSTRACT.]

THE deep-etching of steel by means of concentrated acid, *e.g.*, hot concentrated hydrochloric acid, is a very important means of revealing the structural condition of such material. The features revealed may be of three types: Chemical—heterogeniety due to segregation, to composition changes accompanying welding, carburization and similar process, to lack of solution and uniform distribution of special addition elements in alloy, steel, etc.; Mechanical—initial stresses due to preliminary mechanical and thermal treatment; Physical—internal fractures and similar discontinuities within the metal.

Steel which is heterogeneous in its chemical composition shows a characteristic roughened surface when etched, corresponding to the variations in composition. This roughening is due to the greater solubility of certain portions particularly the non-metallic inclusions, sulphide, oxide, etc., and to the deepening and widening of the pits resulting upon the removal of these inclosures.

As specimens typical of highly stressed material, hardened steel balls were used. The stresses, due to the mechanical and thermal treatment the balls had received, were often of sufficient magnitude as to cause the balls to crack spontaneously when subjected to the action of concentrated acid. The behavior of steel in this respect is identical with the corrosion-cracking of brasses and bronze under certain conditions.

Physical discontinuities, which may exist within the steel, usually occur as tiny cavities or pores, giving rise to " spongy " metal which is quite readily detected. Certain discontinuities are of the

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[8] Technologic Paper No. 156.

nature of internal fractures, the metal still being in such intimate contact, however, that they are detected only with extreme difficulty. This type occurs rather abundantly in defective rails of the "transverse fissure" type. Similar defects have been found in forgings such as steel axles and tires. Deep etching reveals these internal fissures as short cracks which appear to bear a definite relation in their arrangement to the direction of the stresses to which the piece had previously been subjected.

The presence of these defects in steel previously to etching has never been demonstrated by previous investigators due to the lack of a suitable method. Hence various conflicting opinions have been held as to their nature and the seriousness of the defect. In order to show the presence of such internal cracks a special magnetic method was used. The specimen was polished as for microscopic examination and after magnetizing was bathed in a suspension of *fine* iron dust in kerosene. Discontinuities in the metal were clearly shown by the arrangement of the particles of iron dust along their course. Subsequent etching tests showed that each "crack" revealed by the etching is due to the widening and deepening of a *preëxisting* internal fracture in the steel. These defects are essentially fractures circular in area which occur across what is otherwise sound metal. By suitable means the metal may be opened up along the line of the defect showing that there is a definite discontinuity within the metal and no coherence at all. These areas are identical in appearance with the starting point of very serious defects known as "transverse fissures" in rails.

ESTIMATION OF NITRATES AND NITRITES IN BATTERY ACID.[9]

By L. B. Sefton.

[ABSTRACT.]

FROM among the various methods suggested for the estimation of nitrates and nitrites in small amounts and admitting of a sulfuric-acid medium, three methods for the determination of nitrates —the Diphenylamine, the "Hydrostrychnique," and the Brucine— and three for the determination of nitrites—the Iodide, the Indol,

[9] Technologic Paper No. 149.

and the Dimethylaniline—were selected and studied with reference to their use in testing battery acid.

The Diphenylamine test for nitrates and the Iodide test for nitrites were found to be wholly unreliable. It was found impossible to estimate nitrates in the presence of nitrites: the "Hydrostrychnique" and the Brucine test reacted with nitrites in the same way as with nitrates so that the results of these methods must be expressed in terms of nitrates and nitrites. In the absence of iron, the "Hydrostrychnique" or a modification of the Brucine test is recommended. In the presence of iron, only the original Brucine test may be used.

It was found that nitrites could be estimated in the presence of nitrates and best by the Dimethylaniline method.

A NEW INTERFERENTIAL DILATOMETER.[10]

By Irwin G. Priest.

[ABSTRACT.]

THIS paper describes new instruments and methods for measuring very small changes in the lengths of samples which are too small to be examined by the Fizeau interferential method. Only a single small pin is required as a sample.

The method of measurement depends upon the change in width of interference fringes instead of their displacement as in the Fizeau method. The outline of the method on this basis is briefly:

1. One of a pair of nearly, but not quite, parallel interferometer mirrors is supported at one point by the sample and at two other points by a standard substance of known expansivity, the perpendicular distance from the bearing point of the sample to the line connecting the bearing points of the standards being known.

2. The standard and the sample are so adjusted that the fringes are parallel to the line connecting the bearing points of the standard.

3. Any difference in expansivity of the sample and the standard causes the interference fringes to change their widths with change in temperature. The number of fringes between two fixed reference lines on one of the mirrors is determined at each of the two temperatures in question.

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[10] Scientific Paper No. 365.

4. From the above data the difference in the expansion of the standard and the sample can be computed.

The new method gives results of the same accuracy as the Fizeau method, while it has the following advantages over the latter:

1. Only one small pin is needed for a sample.

2. Contact errors are decreased and the error due to "creeping" of the cover plates is eliminated.

3. Computations are simplified by having the standard and the sample nearly equal in length.

4. The trouble of counting fringes while the temperature is changing is eliminated entirely without the necessity of making observations on fringes of more than one wave-length.

5. The correction for change of refractive index with the temperature and pressure of the air in the container is eliminated without evacuating the container.

6. The method is especially advantageous in determining small differential expansions, for the difference in expansion of small samples may be determined directly by carrying them together through the same temperature cycle.

PREPARATION AND REFLECTIVE PROPERTIES OF SOME ALLOYS OF ALUMINUM WITH MAGNESIUM AND ZINC.[11]

By R. G. Waltenberg and W. W. Coblentz.

[ABSTRACT.]

THIS paper gives the manner of preparation and determination of the spectral reflective properties of alloys of aluminum with magnesium and with zinc.

The reflectivity measurements were made with a spectroradiometer consisting of a mirror spectrometer, a fluorite prism and a vacuum bismuth-silver thermopile. It was found that all of these alloys tarnish in time and hence are not suitable for mirrors where permanency is of prime importance. The compound of aluminum and magnesium, Al_3Mg_4, deteriorates less rapidly than any of the other alloys examined and could be used in apparatus where a highly reflecting mirror is desired for a short time. A re-

[11] Scientific Paper No. 363.

flectivity of 92 per cent. at 0.7μ was obtained with this compound.

The zinc-aluminum alloy has a minimum of reflectivity at 0.9μ. An examination of pure zinc disclosed a similar reflectivity minimum at 1.0μ.

THE DETERMINATION OF CELLULOSE IN RUBBER GOODS.[12]

By S. W. Epstein and R. L. Moore.

[ABSTRACT.]

After a discussion of the value of a procedure for determining cellulose in rubber goods and consideration of the lietrature on the subject, the proposed method is discussed.

Method. Sample is digested with cresol at 160–185° C. for four hours to dissolve the rubber. Filtration is facilitated by addition of 200 c.c. of petroleum ether. After washing with benzol, 10 per cent. solution of hydrochloric acid, water, and acetone, the material is dried and weighed. It is then acetylated by heating for thirty minutes at 75° C. in a mixture of 15 c.c. of acetic anhydride and 0.5 c.c. of concentrated sulphuric acid. This is filtered on a weighed Gooch, washed with 90 per cent. acetic acid and then with acetone and dried and weighed. Loss in weight is recorded as cellulose.

Under *Results of Analysis* are given a number of test compounds, containing varying amounts of cellulose in the presence of various combinations of compounding ingredients. The results by method given indicate its gratifying accuracy. A number of alkali reclaims are given along with cellulose content as obtained by method proposed.

It is shown how the percentage of cotton can be obtained in the presence of leather.

Leather, wood, jute, and cork are considered. These are broken down by cresol at 185° C. For this reason it is suggested that rubber be digested in cresol for sixteen hours at 120° C. when the presence of these is suspected. At this temperature the basic substance of these materials is retained intact.

Acetylation gives:

95 per cent. of the wood.
90 per cent. of the jute.
70 per cent. of the leather.
21 per cent. of the cork.

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[12] Technologic Paper No. 154.

An approximation of the amount of the cork present is obtained by treating the residue after acetylation with 2 per cent. solution of sodium hydroxide and strong bromine water, in order to give the unacetylated cork. The loss in weight represents 70 per cent. of the total amount of cork present.

It was found impossible to determine each of these ingredients separately, and therefore it was decided to determine them collectively by the acetylation method, and to test for the presence of each by means of proper stains and microscopic examination.

Rubber Plant Survey of Western North America.—HARVEY M. HALL and THOMAS H. GOODSPEED (*University of California Publications in Botany,* 1919, vii, 183–264) give an account of chrysil, a new rubber, of high grade, which vulcanizes without difficulty. *Chrysothamnus,* or rabbit bush, is a genus of shrubs; its most important species is *Chrysothamnus nauseosus,* of which 22 varieties are known; plants of 12 of these varieties were examined and found to contain chrysil. The plants of this species are large shrubs; they grow readily from seed, and attain maturity in six to eight years; the average weight of a plant varies from 4 to 6 pounds. The species ranges throughout western North America, is most abundant in Colorado, Nevada, and Utah, and often occurs on alkaline flats. The plants with the largest chrysil content were found in Nevada and California. The chrysil occurs in the cells of the plant and not as a latex; it is most abundant in the tissues at the soil line. The cortex contains most chrysil, followed by the medullary rays; young twigs and leaves contain but a slight amount; of the root, only the upper portions (4 inches) contain chrysil. The average chrysil content varied from 2.83 to 1.97 per cent. or less, according to the species. One individual plant yielded 6.57 per cent. The rubber was obtained from the finely ground plants. Fats and similar substances were removed by extraction with acetone. The fat-free residue was dried, and then extracted with benzine to obtain the chrysil. Hall (*Ibid,* 1919, vii, 159–181) describes the varieties of *Chrysothamnus nauseosus* and their geographical distribution. According to Hall and Goodspeed (*Ibid,* 1919, vii, 265–278), rubber also occurs in certain other species of *Chrysothamnus,* and in certain species of the genus *Haplopappus.* In some species rubber was present to the same extent in root and stem (*e.g., Haplopappus nanus*); in other species the root contained practically all the rubber present in the plant (*e.g., Haplopappus ericoides*). Sixty-four other species of shrubs were tested, and found not to contain rubber.

J. S. H.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

THE COMPOSITION OF THE OIL FROM THE SEED OF THE HUBBARD SQUASH.[1]

By Walter F. Baughman and George S. Jamieson.

[ABSTRACT.]

OIL expressed from squash seed by an expeller was refined by the well-known alkali process and bleached with fuller's earth. The refined oil had a yellow color and a bland fatty taste. The unsaturated fatty acids were separated from the saturated acids by the lead salt ether method and bromine addition products were prepared. Analyses of these compounds gave the amounts of oleic and linolic acids in the original oil. Methyl esters were prepared from the saturated acids and were subjected to fractional distillation under diminished pressure. From the iodine numbers and saponification values of the different fractions and the residue the amounts of unsaturated acid were calculated, the mean molecular weights of the saturated acids were found, and the weight of each saturated acid in each fraction was calculated.

The Hubbard squash seed oil was found to consist of the following:

Glycerides of	Palmitic acid	12.73 per cent.
	Stearic acid	6.12 per cent.
	Arachidic acid	0.04 per cent.
	Oleic acid	36.58 per cent.
	Linolic acid	43.34 per cent.
	Unsaponifiable matter	1.06 per cent.

THE COMPOSITION OF OKRA SEED OIL.[2]

By George S. Jamieson and Walter F. Baughman.

[ABSTRACT.]

OIL expressed from okra seed by an expeller was examined physically and chemically by the methods used for Hubbard

* Communicated by the Director.

[1] Published in *J. Am. Chem. Soc.*, **42**, 152–7 (Jan., 1920).

[2] Published in *J. Am. Chem. Soc.*, **42**, 166–70 (Jan., 1920).

squash oil (see above). The oil, which amounts to about 15 per cent. of the seed, was found to have the following composition:

Glycerides of	Palmitic acid	27.23 per cent.
	Stearic acid	2.75 per cent.
	Arachidic acid	0.05 per cent.
	Oleic acid	43.74 per cent.
	Linolic acid	26.62 per cent.
	Unsaponifiable matter	0.37 per cent.

A CHEMICAL STUDY OF THE RIPENING AND PICKLING OF CALIFORNIA OLIVES.[3]

By R. W. Hilts and R. S. Hollingshead.

[ABSTRACT.]

THE results of an investigation of the chemical changes which occur in California olives during ripening and during pickling indicate that the best index of maturity for olives, both fresh and pickled, is the percentage of oil in the fruit flesh. Allowance, of course, must be made for variations due to the variety of the olives and the locality in which they are grown. A minimum oil content of 17 per cent. in the flesh is offered as a tentative standard of maturity for Mission olives and other common varieties, except the Manzanillo, Ascolano, and Sevillano. A minimum oil content of 15 per cent. is recommended as a tentative standard for Manzanillo olives. No standards for maturity are recommended for the large-fruited olives, Ascolano and Sevillano, which must be gathered when relatively immature. These olives, however, should not be sold under the designation "ripe."

Because of the great variations noted in the composition of olives of the same variety grown in different localities, it probably will never be practicable to set definite and hard fixed minima for oil in mature olives, and the proposed standards must be applied with caution.

It was found that some of the abuses, the report of which led to this investigation, did exist, immature olives having often been pickled and colored to simulate pickled ripe olives. The data given in the bulletin will make possible the detection of gross frauds of this nature.

[3] Dept. Agr. Bull. 803 (Jan. 24, 1920).

THE OCCURRENCE OF MELEZITOSE IN HONEY.[4]

By C. S. Hudson and S. F. Sherwood.

[ABSTRACT.]

IT has been known since ancient times that bees collect mannas during droughts because floral nectar is not then abundant. Turkestan manna and likewise a manna from the European larch tree have long been known to contain the rare sugar melezitose, and recently the authors[5] found over 70 per cent. melezitose in a manna from the Douglas fir of British Columbia. The identification was made by chemical means and also by optical crystallographic examination by Dr. Edgar T. Wherry.[6] While considering the possibility that melezitose may have been present in some kinds of honey and escaped detection in the past, the authors received a sample of comb honey, of honey-dew type, from Port Royal, Pennsylvania, which had crystallized solidly in nearly all the cells. The crystals were not d-glucose, the sugar that frequently crystallizes from honey, but were pure melezitose. Two samples of honey-dew honey from Maryland have also been found to contain crystalline melezitose. An investigation by Dr. Edgar T. Wherry of the origin of these three lots of honey discloses that the bees collect a sweet fluid deposited on the young twigs of the Virginia pine (*Pinus virginiana*) by a soft scale insect (*Toumeyella parvicorne* (?) Ckll.), or at other times by an aphid (*Lachnus pineti* (Fab) Koch.), and store away this material in place of floral nectar. The fluid itself was found to contain much melezitose. Analytical data on this type of honey are recorded, and a way for the approximate estimation of melezitose in such products is described. Since melezitose has already been identified in mannas from two conifers, namely, the European larch and the Douglas fir, and is now found in an exudation from a third, the Virginia pine, the question naturally arises whether melezitose may not be present in the sap of most coniferous trees.

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[4] Published in *J. Am. Chem. Soc.*, **42**, 116 (1920).

[5] Hudson and Sherwood, *J. Am. Chem. Soc.*, **40**, 1456 (1918).

[6] Wherry, *J. Am. Chem. Soc.*, **42**, 125 (1920).

A Cheap and Simple Micro-balance. J. H. SAXBY. (*Proc. Phys. Soc. London,* vol. xxxii, Part I.)—The balance costs about eighteen pence, is designed for maximum loads of 5 milligrams to as many decigrams, has an accuracy of one part in 1000 and is rapid in action. A horizontal beam is fixed in position. To each end is attached a vertical beam supported slightly above its centre of gravity and turning readily about a horizontal axis. A light thread is stretched from the lower end of one vertical beam to the lower end of the other. Its length is about 2 feet. The load to be weighed is suspended at the middle of this thread. The weight draws the two ends of the vertical beams together and thus a considerable sinking is caused. A calibration curve is obtained by the use of known weights.

The beams were metal ("Meccano") strips perforated at regular intervals with holes.

G. F.S.

Note on a Modified Form of Wehnelt Interrupter. F. H. NEWMAN. (*Proc. Phys. Soc. London,* vol. xxxii, Part I.)—For the ordinary Wehnelt interrupter a P.D. of from 80 to 100 volts is needed and besides its life is limited by the disintegration of the metal. In the modified type a plate of aluminum of 50 sq. cm. area and a platinum wire sealed in a glass tube are the electrodes. The minimum potential difference necessary is 18 volts and the interrupter can work for ten hours with little destruction of the platinum wire. When used with a direct current the wire must be made the positive electrode. The current is, of course, intermittent and the frequency of the interruptions increases with the applied volts.

When the interrupter is used with alternating current the wire is positive with respect to the aluminum. When joined in series with the primary of an induction coil and with 100-volt A.C. mains the current in the secondary of the coil was unidirectional and very steady—suitable for X-ray production.

G. F.S.

The Constitution of the Elements. F. W. ASTON. (*Nature,* December 18, 1919.)—By the use of his positive-ray spectrograph the author finds carbon and oxygen to be pure but neon, chlorine and mercury to be mixtures of isotopes. Neon is a mixture of isotopes of atomic weights 20 and 22, chlorine of at least two isotopes of atomic weights 35 and 37, while mercury consists of a mixture of three or four isotopes with atomic weights in the vicinity of 200.

A fact of great significance is that of more than 40 determinations of atomic and molecular weights, all, with no exception at all, prove to be whole numbers, carbon and oxygen being taken as 12 and 16.

G. F.S.

NOTES FROM THE U. S. BUREAU OF MINES.*

CO-OPERATIVE PETROLEUM WORK, WYOMING.

By T. B. Tough and B. H. Scott.

The Rocky Mountain Petroleum Association was formed to raise a fund to be placed at the disposal of members of the staff of the Bureau of Mines for giving advice and assistance in regard to the drilling of wells in the Wyoming oil fields, since preliminary examination indicated that operations on government lands were resulting in considerable waste in both oil and gas production. In this way $30,000 was made available, and work was started on Buck Creek Well No. 4, in the Lance Creek field, which had been invaded by water. Between September 16 and November 14, 1919, the water was successfully shut off and the well began flowing at the rate of 700 barrels per day. The value of the output of this well for the subsequent month alone will more than repay the cost of such work in the entire Rocky Mountain region for a year. In California, where similar work has been carried on, the result has been such an improvement in general practice that companies that formerly completed only 30 per cent. of their wells in good condition now complete 80 to 90 per cent. Another result of such work is that production in California has been maintained steadily from year to year without the help of phenomenally large wells to maintain the output.

REMOVAL OF LIGHTER HYDROCARBONS FROM PETROLEUM.

By J. M. Wadsworth.

California practice has developed the desirability of subjecting petroleum to a preliminary refining to remove the lighter hydrocarbons. When the crude oil is to be burned, it is obviously wasteful not to first remove the valuable light constituents. As a safety precaution it is also desirable to remove the lighter fractions from oil before storage to prevent losses from evaporation.

* Communicated by the Director.

In addition, such a process dehydrates and cleans the oil. The character of the California oil and the use to which it is put accentuates the desirability of such a method. In considering the construction of such a plant the following factors need to be taken into consideration: Will the volume of residuum be large enough for heat exchange with the crude? Can the vapors be used to reduce the cooling water requirements? What products will be made and what volume of each? Will the saving of fuel justify the capital and maintenance on the apparatus required? What type is suitable for the oil? What method will best recover the heat from the stack gases? Has every possible provision been made for the recovery of heat? A number of California plants, having a total capacity of 2,300,000 barrels of crude monthly and producing an average yield of 18 per cent. "tops," or light fraction, were studied and the detailed results of this study are presented in Bulletin 162 of the Bureau of Mines. The cost of the plants per barrel daily capacity varied from $2 to $28.55; the total fuel oil consumed under the stills and boilers ranged from 1.07 to 3.69 per cent. of the crude treated; and the combined efficiency of furnace and stills ranged from 34.8 to 66 per cent.

CONDITIONS IN THE EUROPEAN PHOSPHATE MARKET.

By W. C. Phalen.

THE farmers of France have had since 1914 only about one-third of the phosphate ordinarily consumed and even though there are large deposits in the French colonies of Tunis and Algiers, only 80,000 tons were brought to France in the first quarter of 1919, as compared with 122,000 tons in the same period of 1918, the difficulty being one of transportation. It is reported to be the intention of the French government to regulate the exportation of phosphate from Africa, which has been going freely to England and Italy, so as to assure an adequate supply for France. Only about one-half of the needs of France have been allocated, owing to the difficulties of transportation and of the 700,000 tons allocated for the first six months of 1919 only 30 per cent. was actually imported. The French specifications as to soluble phosphate, iron, and alumina are not so strict as in other European countries, and the market there is therefore in a position to take

care of considerable amount of medium to low-grade phosphate.

In Italy the demand for phosphate is growing because of the need for increased crop production. Before the war the importation of phosphate into Italy was largely controlled by German firms, but a number of Italian importers and consumers are in direct touch with American producers.

About two-thirds of the phosphate imported into Spain comes from Africa and the remainder from Florida. About a half million tons of superphosphate were consumed in Spain yearly before the war, but only about one-half that was consumed in 1918. It has been estimated that two million tons could be consumed yearly to advantage, but the growth of the market will doubtless be slow. Of the amount of superphosphate used in 1913, 80 per cent. was manufactured in Spain and the rest imported from England, France, Belgium, and Holland.

MINOR NOTES.

Storage Battery Locomotives.—At a conference held in Harrisburg, Pa., January 27th, safe use of storage-battery locomotives underground was discussed and the chief inspector of the Pennsylvania Department of Mines stated that if the locomotives were tested and approved in accordance with Schedule No. 15 of the U. S. Bureau of Mines, they would be acceptable to the State of Pennsylvania.

Incombustible Gas.—Some gas wells of the mid-Continent field yield gas that is practically incombustible. Samples collected from a well drilled recently near Homing, Oklahoma, showed less than 10 per cent. hydrocarbons.

Ultra-rapid Moving Picture Photography. H. ABRAHAM, E. BLOCH, and L. BLOCH. (*Comptes Rendus, Acad. des Sciences,* vol. clxix, No. 22, 1919.)—A small Leyden jar charged to 5000 volts discharges across a gap and illuminates the object to be photographed. As soon as the jar has discharged it recharges from a large condenser. The sparks pass at the rate of more than 50,000 per second, and have a duration of about a millionth of a second. They are therefore practically instantaneous. The successive images are received on a sensitive film in rapid motion. "It is easy to take moving picture views with a speed of more than twenty thousand photographs per second."

G. F.S.

Experiments on Gravitation. L. MAJORANA. (*Comptes Rendus, Acad. des Sciences,* vol. clxix, Nos. 15 and 17, 1919.)—A lead sphere of mass 1274 g. suspended from the right arm of a balance was counterpoised by a similar sphere on the left arm. Both spheres are surrounded by walls of the same shape. The first sphere has its centre coincident with the centre of a cylinder with vertical axis which can be filled with mercury of mass 104 Kg. The liquid is kept from touching even the protecting wall about the lead sphere. A vacuum was maintained within the balance case and all thermal, electrical, magnetic, and electromagnetic effects were eliminated. As the result of a lengthy series of experiments, conducted at night or on days of general strike, it was found that the lead suffered a loss of weight of 0.0009 mg. when it is surrounded by the mercury, that is, a loss of 7.10^{-10} of its weight. This is of interest, since hitherto it has been believed that the force of gravity acts through matter just as if it were a vacuum.

G. F.S.

American Diet Changing. (*Weekly News Letter, U. S. Department of Agriculture,* January 21, 1920, vol. vii, No. 25, p. 8.)—Whether it is because of the increased cost of meat or because people's tastes have changed, the fact remains that Americans are eating 8 per cent. less meat than they were twenty years ago. This is disclosed in a recent dietary survey made by the United States Department of Agriculture.

In this survey 2000 dietary records, each covering a period of seven days, were collected from 1425 families and 575 institutions in 46 states. Sixteen nationalities and many occupations and incomes were represented, as were also both urban and rural localities.

From a summary of 500 of these family records it appears that last year the average cost of food per man per day was 46 cents, with an average return in food value of 3225 calories, 96 grammes protein, 118 grammes fat, and 405 grammes carbohydrate. These figures are in fairly close accord with the dietary standards ordinarily used in discussing such problems of general nutrition.

A comparison of the foodstuffs purchased by the 500 families with the amounts of the same food purchased by 400 families about twenty years ago shows that the amount of meat in the American diet has decreased about 8 per cent., and the amount of grain products about 11 per cent. People are eating more milk, butter, and cheese than they were two decades ago, for the amount of dairy products consumed has increased about 6 per cent. Four per cent. more vegetables and 8 per cent. more fruit are being eaten now.

Some individual food habits undoubtedly need to be corrected, but, judging by these studies, it seems fair to conclude that the average diet seems to be adequate.

R.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting held Wednesday, February 18, 1920.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 18, 1920.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership since last report, 9.

A report of progress was presented by the Committee on Library.

The standing committees for the year 1920–21 were announced.

Mr. H. W. Fulweiler, on behalf of the Committee on Science and the Arts, described the work of Mr. William Wallace Kemp and Mr. William H. Van Horn, of Baltimore, Md., to whom was awarded the Edward Longstreth Medal of Merit, for their Air and Gas Mixing Apparatus. The President presented the medals and accompanying documents to Mr. Kemp, who thanked the Institute for the honor it had conferred upon him and his associate, Mr. Van Horn.

The President then announced that the meeting would become a joint one with the Philadelphia Section, American Chemical Society, and invited Dr. W. A. Pearson, Chairman, to preside.

Dr. Irving Langmuir, of the Research Laboratory, General Electric Company, Schenectady, N. Y., presented the paper of the evening on "The Structure of Atoms and its Bearing on Chemical Valence." A new theory of atomic structures based upon the theories of Rutherford, Kossel and Lewis was offered. By making certain rather simple assumptions regarding the geometrical arrangement of electrons in atoms it was shown how the general properties of all the elements, including those of the eighth group elements and rare earths, can be explained. By means of this new theory it becomes possible to outline a picture of the mechanism of chemical action and the meaning of chemical valence. It leads to a single simple theory of valence which explains and correlates the various theories that have been used in the past. The subject was illustrated by diagrams, charts and lantern slides.

A rising vote of thanks was extended to the speaker, and the meeting adjourned.

R. B. OWENS,
Secretary.

STANDING COMMITTEES, 1920,

OF THE BOARD.

ELECTIONS AND RESIGNATIONS.

Robert W. Lesley, Chairman
Gellert Alleman
Alfred W. Gibbs
Howard S. Graham
Marshall S. Morgan

EXECUTIVE.

E. H. Sanborn, Chairman
Charles Day
Walton Forstall
Alfred W. Gibbs
Alfred C. Harrison

INSTRUCTION.

Lawrence T. Paul, Chairman
George A. Hoadley
Harry F. Keller
Edward V. McCaffrey
James S. Rogers

SECTIONAL ARRANGEMENTS.

Harry F. Keller, Chairman
Gellert Alleman
George R. Henderson
Robert W. Lesley
C. C. Tutwiler

ENDOWMENT.

Coleman Sellers, Jr., Chairman
G. H. Clamer
Alfred C. Harrison
Nathan Hayward
Wm. Chattin Wetherill

EXHIBITIONS.

Benjamin Franklin, Chairman
Francis T. Chambers
Theobald F. Clark
Charles Day
Charles A. Hexamer

PUBLICATIONS.

George D. Rosengarten, Chairman
G. H. Clamer
W. C. L. Eglin
George A. Hoadley
E. H. Sanborn

STOCKS AND FINANCE.

Walton Forstall, Chairman
Cyrus Borgner
Alfred C. Harrison
James S. Rogers
E. H. Sanborn

OF THE INSTITUTE.

LIBRARY.

George S. Crampton
H. J. M. Creighton
Clarence A. Hall
George A. Hoadley
Harry F. Keller
Henry Leffmann
Marshall S. Morgan
Paul Spencer
George F. Stradling
Wm. Chattin Wetherill

MEETINGS.

Gellert Alleman
Charles Baskerville
G. H. Clamer
A. S. Cushman
George R. Henderson
Joseph S. Hepburn
H. E. Ives
A. E. Kennelly
M. M. Price
George D. Rosengarten

MUSEUM.

A. E. Outerbridge, Jr.
Hugo Bilgram
Arthur L. Church
Henry F. Colvin
Charles Day
George A. Hoadley
C. W. Masland
H. H. Quimby
Charles Penrose
Coleman Sellers, Jr.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, February 4, 1920.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 4, 1920.

MR. BENJAMIN FRANKLIN *in the Chair.*

Mr. Charles Penrose was unanimously elected Chairman for the year 1920. The following report was presented for first reading:

No. 2742: Leeds & Northrup's Recording Devices.

R. B. OWENS,
Secretary.

SECTIONS.

Mining and Metallurgical Section.—A joint meeting of the Section and the Philadelphia Chapter, American Steel Treaters' Society, was held in the Hall of the Institute on Thursday evening, January 29, 1920. Prof. A. E. Outerbridge, Jr., and Mr. D. K. Bullens presided jointly.

Albert Sauveur, B.S., Professor of Metallurgy and Metallography of Harvard University, presented a communication, entitled "Fundamental Principles to be Considered in the Heat Treatment of Steel." The fundamental principles underlying the heat treatment of steel were described and discussed with special reference to the results of recent investigations and to apparent exceptions to the general rules. The influence of the work upon the microstructure and physical properties of steel was also considered, as well as the tests to be applied for its study. The subject was illustrated by charts and lantern slides.

After an interesting discussion by the Chairman and others, a vote of thanks was tendered to the speaker.

Adjourned.

ALFRED RIGLING,
Acting Secretary.

Section of Physics and Chemistry.—A joint meeting of the Section and the Philadelphia Section of the American Chemical Society was held in the Hall of the Institute on Thursday evening, February 5, 1920, at 8 o'clock. Dr. Harry F. Keller, on behalf of The Franklin Institute, and Dr. William A. Pearson, on behalf of the American Chemical Society, presided jointly. The minutes of the meeting of January 15th were approved as read.

Richard B. Moore, Sc.D., Chief Chemist, U. S. Bureau of Mines, Washington, D. C., delivered a lecture on "Helium." The history, physical and chemical properties, and occurrence of this rare element were described. An outline was given of the various processes which have been used on a commercial scale for the extraction of helium in quantity from the natural gas of certain regions in the United States. The use of

helium as a substitute for hydrogen in dirigibles and balloons was discussed. The lecture was illustrated with lantern slides and experiments.

The paper was discussed by Messrs. Miner, Norman, and Henderson. On motion of Dr. Walton Clark, a vote of thanks was extended to Doctor Moore. The meeting then adjourned.

JOSEPH S. HEPBURN,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, February 11, 1920.)

RESIDENT.

MR. H. H. PLATT, Mechanical Engineer, 1819 Walnut Street, Philadelphia, Pa.

NON-RESIDENT.

MR. KENNETH R. BROWN, Chemist, Atlas Powder Company, and for mail, Atlas Club, Tamaqua, Pa.

MR. FREDERIC V. HETZEL, Mechanical Engineer, Church and Dean Streets, West Chester, Pa.

MR. A. J. MOORE, Assistant Inspector of Ordnance, U. S. N., Bethlehem Steel Works, and for mail, 511 South 6th Street, Allenown, Pa.

MR. RALPH H. MÜLLER, Student, University of Pennsylvania, and for mail, 2929 North 12th Street, Philadelphia, Pa.

MR. CARL D. PRATT, Chemist, Atlas Powder Company, and for mail, Atlas Club, Tamaqua, Pa.

MR. S. N. VAN TRUMP, Civil Engineer, Chief Engineer, Water Department, Wilmington, Del.

ASSOCIATE.

MR. JOHN C. DA COSTA, 3D, Mechanical Engineer, The Baldwin Locomotive Works, and for mail, 1529 Pine Street, Philadelphia, Pa.

MR. HI NAM HO, Draftsman, Philadelphia Coppersmithing Company, and for mail, 5530 Angora Terrace, Philadelphia, Pa.

CHANGES OF ADDRESS.

MR. WALTER ATLEE, 1209 John Street, Baltimore, Md.

MR. CLAYTON O. BILLOW, 6800 Sheridan Road, Chicago, Ill.

MR. H. C. BOOZ, Berwind-White Coal Mining Company, 1100 Commercial Trust Building, Philadelphia, Pa.

MR. ARTHUR L. COLLINS, 5616 Crowson Street, Germantown, Philadelphia, Pa.

MR. JOHN L. COX, 12 Summit Street, Chestnut Hill, Philadelphia, Pa.

MR. R. E. GILLMOR, Gotham Hotel, 5th Avenue and 55th Street, New York, N. Y.

MR. ROBERT E. HORTON, R. F. D. No. 1, Voorheesville, N. Y.

MR. F. J. LEMAISTRE, 810 Bellevue Court Building, Philadelphia, Pa.

MR. BENJAMIN SMITH LYMAN, 112 Elm Avenue, Cheltenham, Pa.

MR. J. MCGOWAN, JR., 32 N. Front Street, Camden, N. J.

MR. ANGUS K. MILLER, 67 Park Avenue, Saranac Lake, N. Y.
MR. F. W. SUTTON, The Chas. E. Bedaux Co., 4500 Euclid Avenue, Cleveland, Ohio.
MR. JOHN C. TRAUTWINE, 3RD., 1108 S. 46th Street, Philadelphia, Pa.
MR. E. A. UEHLING, 3226 McKinley Boulevard, Milwaukee, Wis.

NECROLOGY.

Hugh McCaffrey was born in Bambridge, Ireland, on June 11, 1843, and died in Philadelphia on December 15, 1919. He came to the United States when a young man and was a pioneer in the manufacture of files in Philadelphia, having established in 1863 the business which bears his name.

Mr. McCaffrey was a member and official of many organizations, and a director of the Beneficial Saving Fund Society. He was greatly interested in the civic affairs of the city of his adoption and at one time acted on an advisory board to one of the Mayors.

Mr. McCaffrey became a member of The Franklin Institute on January 1, 1875.

Mrs. Francis Cabeen, Doylestown, Pa.
Mr. C. J. R. Humphreys, P. O. Box 385, Lawrence, Mass.
Mr. J. Gibson McIlvain, East Downingtown, Pa.
Mr. Edwin F. Smith, 605 Commonwealth Building, Philadelphia, Pa.
Mr. Elwyn Waller, 7 Franklin Place, Morristown, N. J.

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BOOK NOTICES.

ELECTRO-ANALYSIS. By Edgar F. Smith, Blanchard Professor of Chemistry, University of Pennsylvania. 6th edition, small 8vo., 339 pages, contents and index. 47 illustrations. Philadelphia, P. Blakiston's Son & Co. $2.50 net.

Doctor Smith has long been known as a pioneer and authority in the field of electro-chemistry applied to analysis, and a comparison of the earliest edition of the present work with that now at hand will show the extraordinary progress that has been made in the field. Of this progress Doctor Smith can truly say, "all of which I have seen and of which a large part I have been." It is indeed astonishing to the chemist who has not kept in touch with the developments in this field of analysis to note the many applications, especially to metals that in earlier days would have been regarded as quite beyond the reach of accurate electrolytic separations, for it was then thought that no metal that acts upon water or that is readily oxidized in the air could be dealt with quantitatively by electrolysis. The present book gives very satisfactory results with alkali and alkali-earth metals. The ingenious application of potential determination, which is now eliminating the use of indicators, is illustrated in the following experiment, quoted in the language of the book. "Further, it was discovered that the separation of these metals (alkali metals) was possible by observing the difference in the decomposition pressures of their chlorides. For example, place a mixture of sodium chloride and potassium chloride in the inner compartment of the double cup (apparatus described and figured). Rotate the anode and close the circuit. As the point of decomposition of potassium chloride is 4/30 volt higher than that of sodium chloride, raise the pressure to 2/30 volt higher than the 'break point' of the mixture and carefully maintain this pressure to the end of the electrolysis. The sodium chloride alone will be decomposed, its chlorine forming silver chloride at the anode, while its sodium will pass into the mercury and form sodium hydroxide with the water in the outer cup. The disappearance of the 'break' of sodium chloride and the substitution for it of the higher decomposition pressure of potassium chloride are the evidences of the completion of the electrolysis." Doctor Smith states that the method is serviceable in the determination of the small amounts of alkali metals which occur in silicates, which will be a great boon to mineralogists and petrologists.

The book contains an extensive bibliography and constitutes a most valuable addition to analytic literature.

HENRY LEFFMANN.

THE PREPARATION OF ORGANIC COMPOUNDS. By E. De Barry Barnett, B.Sc. (Lond.), A. I. C. 2d edition, small 8vo. 226 pages, contents and index. 54 illustrations. Philadelphia, P. Blakiston's Son & Co., 1920. $3.25 net.

In the preface allusion is made to the extent to which the world has been for many years dependent on Germany for the more recondite phases of applied organic chemistry, and the importance of escaping from this

dependency. It is pointed out that a chemist who is specially familiar by actual practice with a limited number of chemical processes is often prefered to a chemist just from college. This is, however, illusory, as the specialist is often merely a superior type of foreman, and cannot bring to the solution of problems wide knowledge that the college-trained man has. Too often knowledge which cannot be at once turned into dividends is apt to be regarded as merely ornamental. A fact that may seem merely academic will often lead to a valuable discovery. With these views of the author all trained scientists will agree. The object of science is the discovery of truth.

Turning to matter of the book, we find that after about thirty pages of description of apparatus, methods and reagents, the description of the preparing of organic bodies begins with the simpler hydrocarbons, then takes up halogen derivatives, and proceeds to alcohols, aldehydes, acids, nitriles, nitroso- and nitro-compounds, amines, azo- and sulpho-compounds, winding up with a large collection of miscellaneous compounds of complex character, including many of the dyes and so-called coal-tar synthetics. The text is clearly written, the nomenclature up to date, the chemical composition and reactions very frequently illustrated by the use of structural formulas, in which the reviewer is pleased to note that the benzene hexagon is correctly used in accordance with Kekulé's suggestion, a rule that is by no means always followed. That the chemist must still depend upon German authorities for information in this field is shown by the numerous references to German periodicals, but English chemists have never "lost their heads" on this subject, having apparently been guided by the old Roman maxim, "Fas est et ab hostis doceri." A book such as the one in hand will go far towards relieving English-speaking nations of dependence on any continental authority, but scientists cannot, it is to be hoped, ever be brought to ignoring any investigation, whether made by enemy or friend, rival or associate.

Lastly it is proper that the printer should be commended for the excellent typographic work and general neatness of the book.

HENRY LEFFMANN.

A TREATISE ON QUALITATIVE ANALYSIS. By Frank Clowes, D.Sc. (Lond.), F.I.C., and J. Bernard Coleman, A.R.C.Sc. (Dublin). 9th edition, 8vo., 386 pages, contents and index. London, J. & A. Churchill, 1920. $5.00 net.

This book has been long before the public, and the fact that it has reached the ninth edition is sufficient evidence of the service it has been to the student of chemistry in the field to which it is specifically devoted. It follows, in the main, the general arrangement and scope of books on qualitative analysis and is divided into four parts. Part one describes the apparatus and methods employed, part two the analytic reactions applicable for the detection of substances, and part three the procedures to be employed for the detection of these substances, with an appendix of the usual analytical tables. The fourth part is devoted to description of the equipment of a working laboratory for students. It must be confessed that in several respects this chapter is sadly out of date. No

mention is made of electrical installation. The improved forms of Bunsen burners so familiar to American chemists do not seem to have met with favor in the authors' laboratory. The table of atomic weights contains data in regard to all the elements that are within the purview of the book, but as a table it is incomplete. Formulas are used profusely, which is of great advantage to the student, but the reviewer doubts if any advantage results from the use of the symbol "Am" for the formula NH_4. It seems also that in connection with arsenic, some account should be given of the modern methods for detecting minute amounts of that element. They are safer and more interesting to the student than the old-fashioned Marsh method. In the description of Reinsch's test, it is recommended to clean the copper slip by means of emery paper or nitric acid, and then immerse it in the suspected solution which has been acidulated with hydrochloric acid. A much safer way is, however, to immerse the clean slip in dilute hydrochloric acid, boil the liquid for a few minutes and then add the suspected solution. Notwithstanding these few points on which animadversion seems to be required, the book is a valuable aid to the student in qualitative analysis.

HENRY LEFFMANN.

A SHORT HANDBOOK OF OIL ANALYSIS. By Augustus H. Gill, S.B., Ph.D. Revised 8th edition, small 8vo, 204 pages and index. Illustrated. Philadelphia, J. B. Lippincott Company. $2.50 net.

A work that has gone through eight editions in a little over a score of years requires no encomiums from the reviewer, for it is evident that it meets well the purposes to which it is devoted. Doctor Gill's book is well known as a handy volume for the commercial analyst and works chemist, who has to deal with oils, fats and waxes, a group of the highest importance in both industrial and physiologic chemistry. The present edition preserves the forms of the earlier ones, except as to few changes made necessary by the progress of science. Among these changes are a description of the MacMichael viscosimeter and a means of reductions of viscosimetrical readings to absolute units or poises. Several minor tests for lubricating oils have been introduced. Special tests, methods of analysis and descriptions of special oils and greases have been revised where necessary, particularly in the case of drying oils, and methods of analysis of edible and hardened oils and fats are also included. The work is a compact, well-printed guide to accurate chemical procedure in a very important field.

HENRY LEFFMANN.

REFRACTORY MATERIALS, THEIR MANUFACTURE AND USES. By Alfred B. Searle. 422 pages, contents and index, 135 illustrations, 8vo. Philadelphia, J. B. Lippincott Company, 1917.

The author says in the preface: "Few people realize that almost every modern industry is dependent on the use of refractory materials. Without them no steel, brass or other technically valuable metals or

alloys could be reduced, no furnaces could be constructed, and the use of gas and electricity as sources of power would be impossible. The wonderful progress that has been made in many other branches of industry in the last three decades would have been impossible in the absence of refractory materials."

It has therefore become necessary to study the composition and qualities of known refractories, to seek new sources of the old materials and also new forms. One of the most interesting developments along the latter line is the discovery of abundant sources of zirconium compounds, from which excellent refractory products are obtained. When the incandescent mantle was invented, all zirconium compounds were rare minerals, but at the present time the supply is abundant, being principally the mineral known as baddleyite—zirconium dioxide—obtained from the Sao Paulo district in Brazil. Pure zirconium dioxide (zirconia) has a very low coefficient of expansion, and hence is not liable to crack when exposed to sudden changes in temperature. It is, however, too porous for crucibles, but the addition of from 1 to 3 per cent. of thoria or of dead-burned magnesite will reduce the porosity considerably, without seriously diminishing the refractory character. It is somewhat astonishing to read in an English book, the preface of which is dated two and a half years after the outbreak of the European war, statements that the manufacture of articles from zirconia is principally in the hands of certain German firms. The following paragraph is also interesting: "It is a curious fact that with raw materials inferior to those commonly found in Great Britain (in reference principally to fire-clays), the Belgian, German and Austrian manufacturers have produced goods which are more accurate in shape, less affected by severe conditions of use, and generally recognized as being of higher quality than those made here. Moreover, foreign manufacturers have been able to state in detail the properties of their goods under certain conditions, and have been willing to guarantee results to an extent which most British manufacturers have found impracticable." It is probable that the conditions are to-day more favorable to the British makers of refractories.

HENRY LEFFMANN.

PENROSE'S ANNUAL. Volume xxii of the Process Year-Book. Edited by William Gamble, F.R.P.S. London, Percy Lund, Humphries & Co. Small 4to, 112 pages, with many illustrations in monotone and color. 1920. Price, 10 shillings 6 pence.

This beautiful volume is, as usual in such cases, the product of joint efforts by many firms engaged in the manufacture of materials and apparatus employed in the methods of photo-engraving now so familiar to the public. The reviewer can do little more than commend the execution of the illustrations and presswork, for the book must be seen to be appreciated. An interesting feature is to compare one of the very early issues with the present one, which will enable us to see the enormous strides that have been made in the art of processing. In the 1896 issue there were very few color pictures, and these were notably inferior to present-

day work, although at that time considered to be excellent. The modern processes of color photography have advanced so far that the best work now available comes close to the quality of the artist.

HENRY LEFFMANN.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS. Report No. 46. A Study of Airplane Engine Tests. Preprint from the Fourth Annual Report. 40 pages, diagrams, quarto. Washington, Government Printing Office, 1920.

This report is a study of the results of many tests made upon one engine in the Altitude Laboratory of the Bureau of Standards.

Three major variables are considered; namely, speed, altitude, and power; as well as other variables, such as heat distribution, friction losses, carburetion, etc.

The work shows that power varies approximately with the density of the air, decreasing with altitude. The heat supplied in the fuel should be proportional to the density of the air up to nearly 15,000 feet altitude; above this altitude a richer mixture should be supplied. The thermal efficiency based on brake power is a variable, but when based on the indicated power it is nearly a constant for all speeds and altitudes. The sensible heat in the exhaust varies somewhat, but is closely related to the heat rejected on the theoretical (Otto) cycle. The pounds of fuel per I. H. P. per hour is constant up to nearly 15,000 feet altitude, but increases at the higher altitude as a richer mixture is required. When fuel consumption is based on B. H. P., it steadily rises with decrease of density, owing to the effect of a nearly constant friction loss at a given speed.

Report No. 67, Supplies and Production of Aircraft Woods. Preprint from the Fifth Annual Report. 62 pages, maps, quarto. Washington. Government Printing Office, 1919.

The purpose of this report is to present in brief form such information as is available regarding the supplies of the kinds of wood that have been used or seem likely to become important in the construction of airplanes, and the amount of lumber of each species normally put on the market each year. A general statement is given of the uses to which each kind of wood is or may be put, but no attempt has been made to go into a technical discussion of these various uses.

The information contained in this report has been compiled from a great many sources, including principally published and unpublished reports by various members of the Forest Service. Many of the figures given, particularly those relating to amounts of standing timber, are only crude estimates, but until we have a census of the forest resources of the country we shall have to depend largely on guesswork. The figures on production of lumber are taken from the annual lumber census reports and may be relied upon. Estimates as to the proportions of the total lumber production of different species that may be suitable for the manufacture of aircraft are necessarily very general, and are open to modification as methods of sawing or as airplane specifications change.

It is believed that all the species used to any extent or approved for use in American aircraft are included. However, specifications in all probability will be changed as the industry develops. Consequently, the use of many kinds of woods not now considered suitable may eventually be allowed. Copies of the above reports may be obtained from the Committee.

R.

PUBLICATIONS RECEIVED.

The Preparation of Organic Compounds, by E. De Barry Barnett. 2d edition, 273 pages, illustrations, 8vo. Philadelphia, P. Blakiston's Son & Company, 1920. Price, $3.25.

A Treatise on Qualitative Analysis Adopted for Use in the Laboratories of Colleges and Technical Institutes, by Frank Clowes and J. Bernard Coleman. 9th edition, 400 pages, illustrations, plates, 8vo. London, J. & A. Churchill; Philadelphia, P. Blakiston's Son & Company, 1920. Price, $5.

Penrose's Annual: Volume xxii of The Process Year Book, edited by William Gamble, 1920. 112 pages, many illustrations, color prints, plates, quarto. London, Percy Lund, Humphries & Company. Price, 10 shillings 6 pence net.

Canada, Dominion Experimental Farms: Report for the fiscal year ending March 31, 1919. 196 pages, 8vo. Ottawa, King's Printer, 1920. Price, 15 cents.

Canada Department of Mines: Annual Report on the Mineral Production of Canada During the Calendar Year 1918. 80 pages, 8vo. Production of Coal and Coke in Canada During the Calendar Year 1918, 40 pages, 8vo. The Production of Copper, Gold, Lead, Nickel, Silver, Zinc, and Other Metals in Canada During the Calendar Year 1918. 74 pages, 8vo. Ottawa, King's Printer, 1919.

U. S. Bureau of Mines: Bulletin 162. Removal of the Lighter Hydrocarbons from Petroleum by Continuous Distillation, with Especial Reference to Plants in California, by J. M. Wadsworth. 161 pages, illustrations, plates, diagrams, 8vo. Miners' Circular 26. Miners' Safety and Health Almanac for 1920. Published in coöperation with the U. S. Public Health Service. Compiled by R. C. Williams. 51 pages, illustrations, 8vo. Monthly Statement of Coal Mine Fatalities in the United States, October and November, 1919. Compiled by Albert H. Fay. 2 pamphlets, 8vo. Washington, Government Printing Office, 1919.

Utilization of Fish Waste in Canada.—ALFRED J. CURTIS (*Canadian Chemical Journal*, 1920, iv, 4–5) points out that the Canadian waters produce 685,000 tons of fish annually. The annual loss, including fish unfit for human consumption and loss in dressing and marketing, is estimated as 300,000 tons. This waste could readily be converted into fish meal, fish oil, and fertilizer worth aproximately $10,000,000. Under favorable conditions one ton of waste might yield 540 pounds of fish meal worth $20 and 260 pounds of fish oil worth $30; the cost of manufacture would be $10, leaving a profit of $40. J. S. H.

CURRENT TOPICS.

Activation of Carbon. (From *Proceedings of the Thirty-ninth General Meeting of the American Electro-Chemical Society,* September 23–26, 1919.)—In the paper presented by N. K. Chaney some very interesting data have been brought forward concerning the conditions under which charcoal acquires and retains its absorptive and adsorptive powers. Investigation into this field was mainly stimulated by the exigencies of the late war, in which, as is well known, charcoal was used as the main ingredient of the gas-mask, but the facts thus brought forth are being rapidly applied to industrial requirements. The development of a specifically activated carbon is not based solely on mere improvements of the well-known forms of charcoal, but represents a new viewpoint as to the general nature of the coal and the conditions of the surface. In addition to the work of Chaney, that of A. B. Lamb has contributed to the elucidation of new data. The National Carbon Company operated in conjunction with the Chemical Warfare Service in perfecting the gas-mask material for the United States Army.

The main results set forth in the present paper are as follows:

Elementary carbon, except diamond and graphite, exhibits one of two forms, "active" or "inactive."

All primary amorphous carbon consists essentially of a stabilized complex of hydrocarbons, adsorbed on a base of active carbon.

The active modification is characterized by a high specific adsorptive capacity for gases. The inactive form exhibits no specific capacity of that type. The two forms also differ in temperature of formation and susceptibility to chemical action. The active modification is formed whenever carbon is deposited at low temperatures, either by chemical or thermal methods, in general below 600° C., the inactive form from similar decompositions at higher temperatures. The active form is rapidly attacked by oxidizing agents, even slow oxidation occurring at room temperature. Hydrocarbons that decompose above 700° C. do not yield active carbon; acetylene that may be cracked at a temperature of 300° C. does yield it. In the ordinary processes of destructive distillation at relatively low temperatures, active carbon is first formed, which, by virtue of its adsorptive capacity, takes up a certain amount of the hydrocarbons in contact with and stabilizes them so that they are retained under conditions of temperature and pressure at which they would otherwise be quickly eliminated. For example, quantities of a hydrocarbon resembling anthracene, the boiling point of which is 360° C., have been iso-

lated from cedar charcoal which had been calcined at 850° C., and chlorine substitutions of hydrocarbons may be obtained in notable quantity by passing chlorine over coconut or other charcoals which have been calcined at similar temperatures. An interesting corollary of these investigations is that anthracite may be regarded as a native primary carbon, since it has been shown to possess an active carbon base saturated with adsorbed hydrocarbons. Bituminous coal and ordinary coke are of the same type.

Primary carbon is essentially an adsorption complex of hydrocarbons, adsorbed by a base of active carbon with or without associated non-adsorbed hydrocarbons.

Secondary carbon is primary carbon partially or completely broken up with formation or introduction of inactive carbon by the high temperature decomposition of its hydrocarbons.

According to the theory, carbon deposited at low temperature and absolutely free from hydrocarbons should be the purest form of active carbon and require no activating process. This was confirmed by preparing carbon at 300° C. by transforming carbon monoxide into carbon and carbon dioxide with the aid of ferric oxide as a catalyst. This carbon proved to be very active.

The discovery of the availability of anthracite and other natural coals and of the possibility of making synthetic primary carbon from pulverized materials by the use of the usual binders saved the country from a critical shortage of materials near the close of the war. The special forms obtained were known as Dorsite (from coconut), Bachite (from anthracite), and Carbonite (from lampblack, powdered coal, or similar material). German carbon was made by impregnating wood with metallic salts, carbonizing and then extracting with acid. This process gives but a small amount of active carbon, but leaves an extremely fine capillary mass. These observations led to the distinction between "capillary capacity" and "specific capacity." The former is distinguished by large capacity at high gas concentrations and by rapid equilibrium between the adsorbent and gas-phase in either direction, the gas being removed as easily as it is adsorbed. "Specific capacity" is characterized by very considerable capacity at low gas concentrations and by an extremely low rate of loss during reversal of the adsorption process.

Through these researches it has been made possible to prepare intelligently such active carbon on the large scale from whatever source may be the cheapest or most desirable. The unique properties of the material both as a catalyst and adsorbent suggest that it will find many applications in the industries.

H. L.

Earth-current Telegraphy. CAPT. L. C. CARUS-WILSON. (*The Royal Engineers' Journal*, January, 1920.)—If an electric current is sent into the earth at one point and leaves it at another, it

travels from one point to the other, not in a straight line, but along a series of curved paths. If the two free ends of two wires attached to a receiving instrument are inserted into the earth at some distance from each other, and not far from the earth current just mentioned, they will have a difference of potential and a current will flow through the receiving instrument. If it is a telephone current which flows through the earth, and if the receiving instrument is a telephone, then in the latter may be heard the message picked up from the earth. To magnify the sensitiveness of the receiver the French introduced the "Low Frequency Amplifier," three valves in cascade, with total magnification of 125, by which telephone conversations could be overheard at a distance of several thousand yards. The Huns captured one of the valves, saw for what it was used, and at once applied it themselves. There ensued a war of wits, each side endeavoring to overhear the messages of the other side and to keep its own messages from being intercepted. By the "Fullerphone" messages could be sent by the Morse code without danger of being picked up.

By picking up current from the earth signal messages were sent from one part of the Allied line to another. The secondary of a "Bower Buzzer" (weight 6 pounds and fifty times as strong as a telephone buzzer) was earthed at both ends. The receiving amplifier was likewise earthed at two points about 200 yards apart. The nature of the soil determined the distance over which signals could be sent. In the muddy soil of Flanders the range was 2000 yards under conditions for which the range on the Somme was doubled. The reason was that in the latter region, which has 6 feet of earth with chalk beneath, the electric currents were confined chiefly to a surface layer.

From August to November, 1918, the Royal Engineers erected 326 standard steel bridges and 213 bridges of heavy timber or salved material in the British sector.

G. F.S.

Destruction of Whales by Depth Bombs. (*La Nature,* December 27, 1919.)—To the eye of an observer in an aircraft a submarine and a whale had very much the same appearance provided both were some distance below the surface of the water. This possibility of confusion resulted disastrously to whales in three cases in the North Sea and in one case west of Ireland. In three cases the wounded animal came to the surface. In the fourth case the crew of the dirigible were so certain of their conclusions that they announced by wireless that they had destroyed a submarine, and the news appeared in print. To their discomfiture the mangled body of a whale came to the surface somewhat later in the presence of a torpedo boat.

G. F. S.

A Continuous Process for Electrolytic Regeneration of Chromic Acid is described by RALPH H. MCKEE and SHOO TZE LEO of Columbia University in the *Journal of Industrial and Engineering Chemistry,* 1920,. xii, 16–26. The cell contains a porous diaphragm and lead electrodes. The fresh waste liquor containing chromic salts is fed directly into the bottom of the rectangular cell at one end of the inner or cathode chamber and overflows through an orifice at the other end of the same chamber into the outer or anode chamber, in which the level of the electrolyte is kept slightly lower. The finished product is drawn off at the opposite end of the anode chamber by a siphon or overflow. The best results were obtained when the current density was from 0.5 to 2 ampères per square decimeter of anode surface. The yield was best at room temperature, poorer at both 10° C. and 55° C. A decrease in the size of the cathode for the same anode did not make any appreciable difference. The waste liquor was passed through a sand filter 2 inches deep before entering the cell. Further preliminary treatment was unnecessary; the electric current destroyed all organic compounds present in the liquor. The chromic acid content of the product was up to commercial standard. Approximately 3 kilowatt hours of electric energy were required for each pound of chromic acid regenerated. The saving of sulphuric acid, which is also regenerated in the process without additional cost, amounted to almost as much as the cost of the electric energy required to regenerate the chromic acid. J. S. H.

Power from the Sun. A. A. CAMPBELL SWINTON. (*La Nature,* December 18, 1919.)—The power derivable from the sunlight incident on the earth amounts to about 4,000,000 horsepower per square mile in certain latitudes, or in Great Britain to 1000 horsepower per acre during daylight. The author has little hope for utilizing much of this incident power by the heat engine or by processes of vegetable growth. Solar radiation consists of electro-magnetic waves similar to the waves employed in wireless telegraphy, except that the latter are vastly longer. By thermionic or crystal rectifiers it is possible to get uni-directional currents of electricity from the waves of wireless telegraphy. Mr. Swinton raises the question whether by the use of suitable devices the shorter waves of the solar radiation cannot be made likewise to give rise to electric currents.

G. F. S.

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NUTRITION AND PHYSICAL EFFICIENCY.*

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One of the most awe-inspiring mysteries which the mind of man can contemplate is the power possessed by a tiny mass of matter, the fertilized egg, to develop in a harmonious manner into a composite structure containing tissues and organs with highly specialized functions. Then there follows in all higher animals a period of growth during which the most marked change is an increase in size, but during which there are minor changes in form and structure. No less mysterious is the power of living matter to take from its surroundings food material of a lower grade of organization than itself, and while undergoing continuous destruction through hydrolysis and oxidation, to utilize this food for rebuilding its structures and maintaining its functional capacity unimpaired.

The full-grown man or animal enjoys a period, which varies greatly in length in different species, during which there is no observable decrease in physical power. Ultimately, however, the functional capacity of the tissues diminishes and there sets in a period of involution which is accompanied by changes which we recognize as characteristic of old age.

It is a matter of common observation that the different types

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and races of man, living in different parts of the world and subjected to widely different climate, and engaged in unlike pursuits in order to gain a livelihood, are not all equals either physically or mentally. Herbert Spencer once said that "to be a nation of 'good animals' is the first condition to national prosperity." We can all readily accept this view, but on reflection would agree with Lord Rosebery that "an empire is but little use without an imperial race."

Various attempts have been made to account for the differences in achievement of man in the several parts of the world. Some investigators regard race as the most important factor, and believe that certain races are naturally inferior to others. Huntington of Yale University attributes to climate the most important role in determining the efficiency of man in the several regions of the world. Numerous authors have emphasized the importance of a satisfactory diet for the maintenance of health and of physical fitness, which all agree forms the fundamental basis of achievement. No one up to the present time has, however, been able to make a very strong case in favor of nutrition as a factor. This is witnessed by the number of dietary systems and fads which have been offered to the public. While one enthusiast extols the virtues of abstemiousness, another warns against it and points to the high meat consumption of the successful nations of the earth. While thousands of dyspeptics adopt vegetarianism, others explain the remarkable health of centenarians as due to the bacillus of sour milk.

The general public becomes suspicious when approached by a multiplicity of counsellors seeking favorable consideration when the character of their advice is bewildering. The trouble lies in the lack of definite and accurate knowledge concerning the chemistry of nutrition which has prevailed until very recent times. While many of the wisest philosophers would agree with the statement expressed editorially by the *British Medical Journal* in 1904, "The study of dietetics should be looked upon as very nearly if not quite as important as the study of therapeutics," much disagreement would, nevertheless, be encountered in their views as to the best dietary habits to adopt. Fortunately chemistry has come to rescue dietetics from its state of empiricism. In the hands of the chemist new methods of experimentation have been developed which have made possible the solution of

problems of detail which were not dreamed of in the philosophy of dietitians. Before discussing the relation of the diet of man to his well-being and efficiency I want to explain the simple procedure which has brought order out of chaos in the field of nutrition.

The best chemical analysis of a food-stuff which the chemist is able to make determines the amounts of protein, carbohydrate (starches and sugars), fats and oils and mineral salts which it contains. For more than thirteen years it has been known, however, that when a mixture of this list of substances, each carefully purified, is fed to a young animal the latter cannot grow or long remain alive. The reason for this was very difficult to ascertain, for it is due to the lack of certain substances of a moderately unstable nature, the existence of which was not suspected. Certain species of animal, as the rat, appear to require, in addition to the long-recognized dietary complexes, but two of the unidentified dietary essentials. The most common designation of these is perhaps the term "vitamine," which includes fat-soluble A and water-soluble B. No less than twenty-five names have been invented for these substances. Other species of animals, such as man, guinea-pig and monkey, require three, the additional one being called water-soluble C. These terms have been applied provisionally pending the discovery of the chemical natures of these interesting substances.

Modern research has shown that there are very great differences in the biological values of the proteins from different sources. This difference depends on the fact that the proteins in different food-stuffs yield varying amounts of the amino-acids or digestion products. If the yield of the several amino-acids is such as to make possible the efficient transformation of food proteins into tissue proteins the proteins have a high value. If, however, one or more of the amino-acids is present in such small amounts as to make it impossible to utilize the more abundant amino-acids, they form the limiting factor which determines the value of the protein in nutrition. Many of these digestion products are certainly indispensable in the diet, since they cannot be synthetically produced within the tissues. In considering the value of a natural food-stuff or of a diet consisting of a variety of substances, the idea of quality of protein enters into the calculations of the dietitian of to-day.

It has been abundantly demonstrated that the mammal requires for satisfactory nutrition nine mineral elements in addition to the essential organic complexes, in order that its diet may be adequate. These are calcium, magnesium, sodium, potassium, chlorine, phosphorus, sulphur, iron and iodine. These can be supplied in the form of inorganic salts except in the case of sulphur which must be contained in the diet in the form of the sulphurized amino-acid cystine. It is doubtful if there is an order of relative importance among these, for it appears that all are indispensable. There must be present in the diet either glucose or a carbohydrate which can be converted into glucose in the body. Cane sugar, glucose, beet sugar and the starches serve this purpose.

It seems highly probable that fats and substances closely related chemically to the fats are entirely dispensable in the diet. Up to the present time it has not been found possible to properly nourish an animal with a diet free from this class of compounds because one of the unidentified dietary essentials is associated only with certain fats. Therefore, in working with a diet made up of purified food-stuffs it has been necessary in every case to add one of these fats, not because of the fat itself, but because of the presence of an unknown substance (fat-soluble A) which is contained in it.

It will be interesting to inquire about the distribution of the three unknown substances which the diet must contain. The substance fat-soluble A is found in butter fat and egg yolk fats, and in the fats from the interior of the cells of the glandular organs of animals (*e.g.*, the liver, the kidney) in greater abundance than in any other foods. The next foods in importance as a source of it are the leaves of plants. The seeds, tubers and fleshy roots are relatively poor in this substance.

The water-soluble B dietary factor is widely distributed among natural food-stuffs. The only foods which are in common use which are lacking in it are polished rice, the sugars and starches, and the fats and oils from both animal and vegetable sources. A group of foods which are very poor sources of it are white flour, degerminated corn meal, macaroni, spaghetti, and other products prepared principally from bolted wheat flour. All whole seed products, tubers and fleshy roots, leafy foods, milk and eggs contain it in relative abundance. Muscle cuts of meats are very poor in it, but the glandular organs contain it in abundance.

The water-soluble C is abundant only in fresh vegetables, fruits and fresh milk from cows which are on pasture. Cooked and dried foods have in great measure lost their peculiar dietary properties with respect to this substance.

The effects of specific starvation for one or another of these three substances are of special interest. Each of them is necessary in the diet in order to prevent the development of a specific syndrome which we call collectively deficiency diseases.

One of these, which is caused by a lack of fat-soluble A in the diet, is characterized by a change in the eyes, in which edema, inflammation, and in some cases perforation, are the most important. Much remains to be learned regarding the histology and pathology of starvation for this dietary complex. Without it growth is impossible, and death soon supervenes. There is much evidence that a lack of a sufficient amount of fat-soluble A is one of the factors associated with the etiology of rickets.

A lack, either relative or absolute, of the second dietary factor of unknown chemical nature, water-soluble B, leads to the development of a condition of polyneuritis which in man is known as beri-beri. The paralysis is the most striking general feature of the disease.

The third of the dietary complexes under consideration is that which prevents when it is present in the diet the development of the syndrome of scurvy. It is the least stable of the three. The antineuritic substance is the most stable.

For several years the three substances just discussed have in the popular mind overshadowed in importance the long-recognized dietary essentials. It should be emphasized at once that there is no basis in fact for considering them any more important than the proteins or than any one of the essential mineral elements. All are indispensable components of the diet, and are, therefore, of essentially equal importance. Any appraisal of the quality of the diet must include a consideration of the quality and quantity of protein; the content of each of the necessary mineral elements; the content of each of the substances which are concerned with the etiology of the deficiency diseases, and the availability of its carbohydrates.

After the factors which operate to make a diet complete and satisfactory were appreciated, a series of studies were carried out with a view of determining the nature and extent of the dietary

shortcomings of each of the more important of our natural food-stuffs. In the light of these studies it has become possible to make certain generalizations which are of far-reaching importance in the nutrition of man and animals. On these observations is based a new type of classification of the vegetable food-stuffs depending on the function of the part of the plant from which they are derived.

It has been found that all those parts of plants which have the functions of storage tissues, *viz.*, the seed, tuber and fleshy root, have remarkably similar dietary properties and similar shortcomings. Notwithstanding the great difference between the legume seeds, such as the pea and bean on the one hand and the potato or turnip on the other, they have very nearly the same dietary values in certain respects. All of the cereal grains, legume seeds, tubers and edible roots are deficient in some degree in at least three dietary factors. All contain proteins of relatively poor quality; all contain too little of certain mineral elements, especially calcium, sodium and chlorine, and all are deficient in fat-soluble A.

The leaf of the plant possesses very different dietary properties from the seed. The palatable leaves are alone a complete food for those types of animals which have digestive tracts sufficiently capacious to enable them to eat a sufficiently large amount to meet their energy requirements. This superiority in dietary properties correlates with the special function of the leaf as contrasted with the storage tissue, as the seed, tuber or root. The leaf consists of actively functioning protoplasm supported by skeletal tissue. It is the seat of the synthesis of proteins, carbohydrate and fats. It is the seat of active respiration and metabolism. The seed, tuber and fleshy root represent on the other hand packages of reserve food materials, with few living elements. In general the structures of the storage tissues do not contain all the complexes necessary for the construction of living protoplasm, and are accordingly incomplete foods.

A similar parallel between function and dietary properties can be drawn in the case of the highly specialized muscle tissue on the one hand and the actively metabolizing glandular tissues on the other. The muscle tissue has dietary properties almost identical with the seed, tuber or root in all respects except its richness in protein. It lacks sufficient calcium, sodium and chlorine,

fat-soluble A, water-soluble B, and water-soluble C. The glandular organs such as the liver and kidney are much more nearly complete foods. Indeed, they have all the complexes which are essential for the construction of living tissue, and when supplemented with a carbohydrate, such as starch, approximate much more nearly a complete food than would a similar amount of muscle tissue with starch.

Since there are closely similar dietary properties in the storage tissues of plants and of muscle tissue of animals, it should be expected that mixtures of these even in considerable numbers should not form satisfactory diets. This has been shown in many feeding experiments to be the case. Although it is possible for a young animal to grow on a seed, tuber, root and muscle cut of meat diet, its growth is never normal in rate or extent. It will always be stunted, and will fall below the normal standard of performance in reproduction and rearing of young, and in span of life.

Consistently unsatisfactory results have been secured on diets consisting of wheat flour, corn meal, rice, peas, beans, potato, turnip, beet, rolled oats and round steak. The round steak was included to the extent of ten per cent. of the dry matter of the diet.

This leads us to a consideration of the kinds of diets which do succeed in the nutrition of animals. In a very extensive inquiry, covering twelve years, and based on nearly four thousand feeding experiments, we have succeeded in nourishing animals in an approximately normal fashion with but three types of diets.

It is possible to so select carnivorous foods as to secure a fairly satisfactory diet entirely derived from animal tissues. Young animals cannot grow or long remain in health when restricted to muscle tissue as their sole food. When blood, liver, kidney and other glandular tissues are selected, together with a certain amount of bone substance, the food supply is sufficiently good to lead to normal development. Muscle tissue must be liberally supplemented with blood or glandular organs and bone to make possible success with the strictly carnivorous diet. The carnivorous diet has been used by man occasionally, the Eskimo and some American Indians being examples.

It has been found possible to supplement the seed, tuber, root and muscle meat type of diet with liberal amounts of the leafy

vegetables and secure a fairly satisfactory diet. This requires a liberal supplementing with leaf in order to make good the deficiencies of the remainder of the diet. This type of diet is common among the Orientals.

The third type of diet which succeeds is that derived from cereals, legume seeds, tubers, fleshy roots, with or without meats, supplemented with liberal amounts of milk. Milk is so constituted as to make good all the deficiencies of the classes of foods just enumerated.

It is so important to appreciate the special qualities of the leafy vegetables and milk that I have been accustomed to designate these as the *protective foods*. They are protective foods because they are especially rich in just those elements and complexes in which the storage tissues of plants and muscle tissue are poor.

We will now turn our attention to the application of the facts discovered through animal experimentation to human problems. On careful consideration it strikes one that the more advanced peoples of the world are those who live on the vegetable and meat diet supplemented with milk and its products. The second class in respect to advancement and aggressiveness are those which eat liberally of the leafy vegetables. All strictly carnivorous men live in climates which preclude the development of any high degree of civilization. They have nothing to strive for further than food, shelter, and clothing, and do not accumulate much property.

There can be no doubt that there are carnivorous animals, such as the lion, tiger and jaguar, which live in the hottest parts of the world, yet represent some of the best examples of physical development in the animal kingdom. Neither the heat, monotony of high temperature, humidity or aridity can be said to interfere with physical development.

The tiger thrives in the wet estuaries of Bengal, and the jaguar in the hot and sultry forests of Brazil. The lion is equally vigorous on a margin of the desert. We can find no evidence that climate is a factor of any appreciable importance in the develment of lower animals so far as physical well-being is concerned.

Huntington has made a very plausible case for climate as the most important factor in determining the efficiency of man in the different regions of the world. He points out that the changes in the condition of the weather so characteristic of the northern

parts of the United States and lower Canada in the western hemisphere, and of England, northern France, Holland, southern Germany, etc., are the ideal conditions for stimulating effort, both physical and mental. This assertion he bases upon careful observations on the amount of work of several kinds which workers accomplish in climates varying from that of Connecticut to Florida. Temperature he finds to be the important factor in determining the aggressiveness and ambition of the individual. The farther south the more uniformly warm it is, and the more the climate departs from the typical cyclonic stormy type so characteristic of the northern states of England.

Huntington further correlates the character of the climate of Europe, Asia, Africa, and North and South America, with the state of advancement of their peoples, and finds a remarkable relationship between them. Monotony of climate over long intervals is said to be detrimental to achievement. He eliminates race as an important factor in determining the problem by pointing among other illustrations to the condition of the white people of the Bahamas, who are the descendants of virile Southern settlers, as contrasted with that of other loyalists who at the time of the revolution emigrated to Canada. The former have degenerated into "poor whites" who are too proud to work at menial labor in competition with the negro, and too shiftless to compete with him successfully. The latter are among the most prosperous and progressive citizens of one of the finest examples of a commonwealth in the world.

Huntington sees no great hope for the future of civilization in Asia, Africa or South America, because the white man, who is regarded as superior to the other races, degenerates in their enervating climates. The view is held that when the white man migrates to climates less stimulating than those of his original home, he appears to lose both physical and mental energy. If it is true that under such influences man becomes careless of sanitation and of food, and thus secondarily becomes susceptible to diseases, then indeed there is little reason to hope that the dream of the hygienist can be realized that the tropics can ultimately be made the abode of a cultured population.

Plausible as is the correlation between climate and civilization which Huntington has constructed, it seems to me that another interpretation can be placed on all the data which he presents.

which in the light of what we now know about the effects of diet on health will come nearer the truth. In order to appreciate the importance of diet on the welfare of nations we should consider for a moment the effects of certain types of faulty nutrition on the life history of experimental animals.

When a full-grown animal such as a rat is placed on a diet of seeds, tubers, fleshy roots and muscle meats, it begins to hurry through its span of life, developing the characteristics of old age at a rate double or more the rate observed in a well-nourished animal. It does not succeed well with the nutrition of its offspring, and dies at a fairly early age. The young, if restricted to the diet of the parents, are never their equal physically, have poor success with their young, *live much less long* than the species is capable of, and are subject to infections and abnormalities in a degree unknown in their ancestors. With each succeeding generation weaklings predominate, and the strain dies out within a few generations.

If we apply to the natives of the Bahamas the test of nutrition we find that the diet is of such a character as to account for degeneration in considerable degree within the period since the islands were settled by loyal Tories who were not willing to live under the Stars and Stripes. During this period they have depended for their food supply largely on citrus fruits, pomegranates, pineapples, bananas, melons, yams, potatoes, guinea corn and peas. This it will be noted is a list consisting of fruits and other storage tissues of plants. It has been supplemented with a certain amount of animal foods, principally fish, although some muscle meats from mammals have been eaten. This type of diet it will be remembered is unsatisfactory for the nutrition of an animal over many generations, and leads to deterioration in the stock. This is the condition found in the Bahamas.

On the other hand the people of Canada have lived essentially on the same type of diet as that employed in the northern United States. It includes all the products of field and garden with which we are familiar, together with meats in liberal amounts and dairy products in moderate quantities. The latter is the kind of diet which supports the civilization of England, and also the most progressive European countries as well as that of the northern United States and all other parts of the world which have been peopled by colonization from European stock, wherever the climate will permit.

Another example of the failure of health of European people largely as the result of restricted diet improperly selected is found in Newfoundland and Labrador. There occurs in both these districts the deficiency disease beri-beri, which is caused by lack of a sufficient amount of the dietary essential water-soluble B. The disease is the same that is seen so frequently among the poor laboring classes of the Orient who subsist largely on a diet of polished rice and fish with a few vegetables. The diet in Newfoundland consists, according to Dr. Little, of bread made from bolted wheat flour, tea, fish and salt meats, and raisins. A similar food supply is all that is available in Labrador.

There seems good reason to believe that a second deficiency disease actually occurs among the people of both these regions as the result of their restricted and faulty diet. I refer to a condition popularly called night blindness, which is common especially among men who are out at sea for a considerable period and are subjected to a fare of poorer quality than that obtainable at home. I cannot affirm that it is demonstrated that this is incipient xerophthalmia due to a lack of the unknown dietary complex found most abundantly in butter fat and a few other fats, but there is good reason to believe that it is. Night blindness occurs among men in lumber camps in Canada and elsewhere, and the popular local remedy is to feed the patient milk or cheese. Prompt recovery is said to follow this modification of the diet. In these camps the food supply is frequently limited to bread, salt or canned meats and peas or beans for considerable periods. This again is a seed and meat diet and has been found to be unsatisfactory for animals and for man. The same condition appears to be occasionally met with in Japan, and is not uncommon in parts of India. In both of these countries the popular remedy is the free use of liver as a food, and in India it is recommended that a poultice of liver be applied to the eyes as well. It is safe to say that it is the consumption of the glandular tissue that results in benefit to the eyes of the sufferer. In Japan eel fat and chicken livers enjoy the reputation of being efficacious in the cure of xerophthalmia. Night blindness is reported to be met with in Russia somewhat commonly during the latter part of the Lenten fast. During this period the people restrict their diet largely to cereals, and fail to secure enough of the dietary factor which is concerned with the deterioration of the eyes.

According to the views of those who believe that climate in itself is the chief factor in determining the progressiveness of a people, it will never be possible for a people in central Asia to develop a high state of civilization. It seems worth while to examine into the validity of this conclusion, and in doing so we must make it clear what conditions we accept as a fundamental basis of civilization. If physical well-being as exemplified in excellent development, together with courage and energy, be the first requisite, we have had in the past and have now some notable examples of it among the central Asian tribes. It is necessary, however, in order that a high degree of civilization shall be reached, that a relatively high stage of mental development, together with both social and political fixity, shall be attained.

Of fundamental importance for the development of a highly organized society and a state of advanced civilization is the right kind of religion, since this determines the mental attitude of the individual toward his associates, his neighbors, and his own destiny.

The Mongol hordes of central Asia in the thirteenth to the sixteenth centuries overran and conquered much of western Asia and Europe as far westward as the boundary of Austria-Hungary. Eastward they overran a large part of China, and to the north they were for generations a thorn in the side of the Russians. These Mongols, who played so prominent a part in history, were typical representatives of the sour milk drinkers so common among the pastoral people of all parts of Asia and eastern Europe. At the present time the natives of northwest Mongolia have many cattle, sheep, horses and camels, and derive their sustenance almost entirely from their flocks and herds. The Mongols had all the elements necessary for the creation of a high developent of civilization except the mental attitude toward society which would permit them to respect the personal and property rights of others. They had not the sense of honor and the appreciation of the ethical relations between man and man which are necessary for the establishment of a stable society based on law and order and governed in the interests of the people. Such governments had not at that time gained popularity anywhere in the world. The frame of mind which makes possible these things can be attained only through the establishment of the best system of religion. Climate had nothing to do with these.

The ancestors of the present Turks were likewise a pastoral people and were sour milk drinkers. This constitutent of their diet would alone suffice to make it highly satisfactory, and to insure, in the absence of contagious or of insect-born diseases, an excellent physical development. Such a development is the essential basis of military ambition and success, and was possessed by both the Mongols and the Turks.

The Arab of to-day is an example of the effects of a diet in which sour milk finds a prominent place. He is described by all modern writers as singularly handsome, tall and lithe, with beautifully moulded limbs. Dwarfs, hunchbacks and misshapen persons are seldom seen in Arabia. Few races of humanity excel the Arab either physically or morally. The Arab derives his sustenance in great measure from his animals and milk. Most of the milk is soured, but this forms the most prominent constitutent of his diet. In fact, under the name sheneena, leben, yoghourt, keffir, koumiss, matzoon and dadhi, soured milks have been used from earliest times very extensively over a large part of central Asia as well as Egypt, Palestine, Arabia, Turkey and the Balkan States. Wherever fermented milks are extensively used as food the physical development of the people is unusually good, and the length of life exceptionally long in many instances.

Almost everyone is familiar with the conclusions of the famous Russian bacteriologist Metchinkoff, that the remarkable number of centenarians among the Bulgarian peasantry was the result of the ingestion of sour milk. Metchinkoff believed that the remarkable results of the regular use of their simple diet was due to the lactic acid producing organism which causes the souring of the milk. Its beneficial effects he attributed to the production of lactic acid by this organism in the intestine, and the inhibition of the growth of the harmful putrefactive organisms which develop there in the residues of protein rich foods. He attributed the early aging of mankind and of animals to the absorption of these toxic products.

It is of more than ordinary interest that the most modern investigations in the field of nutrition, carried out by methods which far surpass those of the past in scientific accuracy, support his observations in a general way as regards the beneficial effects of the diet of the people he observed, but detract from the importance of the organism which the milk contains. It is the correc-

tion of the deficiencies of the types of diet which consist mainly of seed products, tubers or fleshy roots and muscle meats, by the inclusion of the protective food milk, which accomplishes the result of greatly improving health and increasing vigor. The bacteria in the milk are of secondary importance.

It is significant also that the Chinese peoples, while possessing a civilization of great antiquity, have lacked certain qualities which are necessary for the formation of a great nation. They were overrun by successive waves of invaders from the northwest during many centuries. The Chinese peoples have lived during all of their history on a diet derived from cereals, legume seeds, tubers, fleshy roots and meats, together with a liberal addition of green leafy vegetables and some eggs. The widespread practice of sprouting grains preliminary to their use as human foods is justified by the results of modern science. The consumption of a large amount of leafy foods has, I believe, been a factor of the greatest importance in promoting their well-being, for, as has been already mentioned, the leaf of the plant possesses dietary properties very different from those of the seed or other storage organ, and these special properties are just those which are necessary to correct the deficiencies of the seed, tuber, root or muscle meats. It is perhaps significant in this connection that the Chinese have, on their diet in which the leaf was almost the sole protective food, been unable to cope with their sour milk-drinking neighbors to the northwest. The descendants of these waves of invaders still live in China, forming classes which have never been assimilated socially.

Huntington believes that the climate of China is not of a nature which can make possible the development of a highly progressive race. This does not seem justified without taking into account certain other factors which are of importance in this connection. We must agree upon what conditions are essential to the development of a high state of civilization before we can agree upon other points.

In a sparsely settled country, where the care of flocks and herds is the only means of livelihood, as is the case over large areas of Asia, pasturage and water are likely to be greatly prized, and the rights to them sharply contested. Enmity between neighbors, lack of education, and the consequent lack of opportunity to gain ideas from others through reading, lack of incentive to

do anything other than seek the protection of the animals which contribute to the comfort of man, are themselves reasons enough to account for the lack of development of a high state of civilization. The climate need not necessarily be responsible for the result. The energy and aggressiveness of peoples who have dwelt in such regions have been repeatedly exhibited in wars of conquest. They have the physical development and intelligence necessary to form the basis of a civilization, provided the necessary conditions for its growth were existent.

It is necessary, in order that a civilization may develop, that food, shelter, clothing, and other comforts of life shall be obtainable without too great a drain on the physical resources of man. There are several reasons why these conditions are best fulfilled in the cooler parts of the temperate zones where the rainfall is most satisfactory for the growth of farm crops.

One of these conditions is that the winter in these regions destroys certain insects which would otherwise destroy the crops. Certain disease-transmitting organisms, such as the cattle tick and the tsetse-fly, which bear respectively the Texas fever and the sleeping-sickness, do not survive the northern winters, and the population in these regions enjoy freedom from these diseases. Cold winters limit the number of species of weeds and other obnoxious plants, and render the production of useful crops less laborious. These are factors of the greatest importance to agriculture and to the well-being of man.

Wherever insect life, such as the destructive ants of tropical forests or myriads of mosquitoes and other insects, detract from the comfort of man, and where rank vegetation renders futile his efforts at clearing ground for cultivation, and where diseases destroy his domestic animals, and place in his own blood disease-producing organisms which rob him of his vitality and ambition, man must have recourse to power other than his own strength to overcome his obstacles. If we give him the aid of machinery and control over suitable sources of power to free him from his crushing burdens, and the aid of science to free him from the scourge of disease, and a diet which causes him to develop a high state of physical perfection, then we may confidently expect of him any development of mental traits consistent with his heredity. It is the aim of those who direct the great agencies for the promotion of hygiene and public health to bring to the

inhabitants of the tropics these blessings. They have faith that these inhospitable regions can ultimately be made the seats of creditable human societies. Not until all of these problems have been solved will man succeed in the less hospitable parts of the world.

One not infrequently sees in discussions of this nature the statement that in the warm regions of the world, where food is easily obtainable, and little shelter or clothing is necessary to the comfort of man, he sinks into indolence, and remains in a state of ignorance and degeneracy. It is urged that only in such a climate as necessitates exertion and foresight during the summer in order to provide food, shelter and clothing with which to pass a severe winter in comfort, will man develop in a satisfactory way the higher virtues of civilization. The theory has been postulated that energy, aggressiveness, frugality, foresight, inventiveness, solicitude for dependents, respect for property rights and the other virtues of man in his most highly advanced condition, are best fostered in a climate which offers vicissitudes, and requires that the life of the individual shall be a struggle with his environment.

We are also told by others, and it appears logical, that so long as man is forced to spend his days in a struggle for existence he cannot develop his higher mental qualities. It is said that the creation of an aristocratic element in society, whose wants are supplied by the labor and sacrifice of a less fortunate group, establishes the ideal condition for fostering the mental growth which comes from reflection and the study of the ideas of others.

There is doubtless an element of truth in each of these views regarding the conditions under which man will best develop his mental capacities. Leisure is essential to certain types of creative thought. Thought is stimulated profoundly through discussion, reading and observations of the phenomena of nature. It is not yet demonstrated, however, that such creative thought is possible or probable only in temperate regions where there are frequent and pronounced changes in temperature.

Let us now return to the relation of the diet to physical efficiency. We have, I believe, a very important problem to solve in the education of the public in many parts of the United States in the proper selection of food. There are large numbers of people who are living too largely on diets derived almost

exclusively from wheat flour, cornmeal and polished rice, all of which represent the poorest parts of the kernels from which they are manufactured, together with tubers such as the potato and sweet potato, and edible roots such as the beet and turnip, supplemented with muscle cuts of meat. This type of diet is not satisfactory for the nutrition of an animal unless it is supplemented with milk or the leafy vegetables in liberal amounts. Of somewhat lesser value as corrective foods are eggs and the glandular organs of animals. These are, however, very low in calcium and so fail to make good this important fault in the diet.

Early aging and low vitality with consequent susceptibility to disease attend the adherence to an unsatisfactory diet. This conclusion has been forced upon my co-workers and myself as the result of thousands of observations on animals restricted to diets varying in quality and restricted as to source. Variety, palatability and appropriate chemical composition as revealed by the best methods of analysis at our disposal do not necessarily guarantee safety.

There is still some scepticism among thoughtful people as to the importance of diet in its relation to health and disease. This is the natural result of several factors. In the first place we accept as normal such conditions of nutrition as we are accustomed to, until it is demonstrated that a higher standard is easily attainable. We are accustomed to see people old looking at thirty to forty years of age, and do not become impressed by it, even though the occasional preservation of vigor to an advanced age shows us what is possible.

The results of malnutrition are not such as to force themselves on the attention. It is attended by languor but not by pain. The effects of heredity and disease are not infrequently responsible for poor physical development which is scarcely distinguishable from that due to faulty nutrition. Man in different regions lives on diets which are widely different in character, and succeeds sufficiently well to seem to warrant the conclusion that it makes little difference what kind of food he takes, so long as it is wholesome and he has enough. The fallacy of such an assumption becomes apparent in the light of what we now know of the dietary properties of each of the more important natural foodstuffs. We can readily see now that man in different parts of the world is living on all the types of diet on which it has been found

possible to nourish animals, and on no other. In certain places he is attempting to live on diets which cost him his vitality by the time he has reached an age which should find him enjoying the full vigor of middle life. This is the seed, tuber and meat type of diet which has already been described.

Throughout parts of India, China, Japan, the Philippines, eastern South America, Newfoundland and Labrador, beri-beri is common, and is due to faulty diet of a character which we well understand. Those who live almost exclusively on a diet of degerminated seed products, tubers, roots and muscle meats do not miss by a very wide margin developing this disease.

While scurvy has become a relatively rare disease among adults, it is still common among infants which are fed heated milk as their sole food. We now know that the antiscorbutic substance, water-soluble C, is the most unstable complex in the diet, and is readily destroyed by heating to the boiling point of water. It is certainly true that many people who live almost exclusively on cooked foods come very near the point of specific starvation for this particular substance, and narrowly escape developing the disease.

Dr. Goldberger of the Public Health Service has done notable work in the study of the relation of the diet to pellagra in the South. He has pointed out that the diet of the pellagrin consists essentially of degerminated cereal grains, starch, sugar, molasses, sweet potatoes and fat pork. But a very small amount of green leafy vegetables are eaten and practically no milk. He has improved the diets of the inmates of institutions where pellagra was a scourge, and observed that this leads to the eradication of the disease. He and his associates were not able to contract the disease by material from the lesions from pellagrins and with their excreta while the experimenters were living on a satisfactory diet. Further dietary studies made in villages where pellagra was common showed that those families which used liberal amounts of milk very rarely contract the disease, and its incidence is highest in those households where least milk and green vegetables are used as food. The liberal use of the articles which as the result of animal experimentation have been discovered to be corrective in character prevents the occurrence of pellagra. The question as to whether it is a disease due to an infectious agent has not been definitely decided.

It is significant that the incidence of tuberculosis among the general population of a city such as Baltimore is very much higher among the group of people who live almost exclusively on the bread, meat and potato type of diet, and use least milk and green vegetables. If we may safely draw deductions from animal experimentation it appears probable that this diet predisposes these people to infection with the tubercle organism.

Many will not agree with this conclusion, but hold that poor hygienic conditions and opportunity for infection, racial susceptibility and certain trades, are the factors which make this disease common. To this view I would reply that we know that the diabetic patient, whose vitality is lowered both by failure of one of the normal processes of metabolism—the oxidation of sugar—and by faulty diet, as is practically always the case, is extremely susceptible to tuberculosis. The medical profession has for many years recognized that one of the most valuable therapeutic agents in this disease is good nutrition. It is interesting to note that on purely empirical grounds the profession long ago came to the employment of a diet for the tubercular which contained liberal amounts of milk and eggs.

A group of people which is of special interest in connection with the problem of susceptibility to tuberculosis is the non-citizen Indian of to-day. There is no group of people anywhere who are dying more rapidly from tuberculosis. They live out-of-doors all summer, and probably have throughout the year as much fresh air as the average city dweller. They do have abundant opportunity for becoming infected because of their careless association with infected persons, and reckless dissemination of infected sputum. Racial susceptibility has been generally regarded as a satisfactory explanation of the prevalance of tuberculosis among these Indians. It seems to me that there is another and more important factor involved, namely, the unsatisfactory character of their food supply. The non-citizen Indian lives on a reservation and is supported by the government. He has, in general, no interest in agriculture, and does not raise much of his food. His live stock usually consists of horses. He lives on the products which he buys at the agency stores, and these, unfortunately, consist almost wholly of degerminated cereal products, legume seeds, tubers and meats. It seems plausible at least that this diet is an important factor in rendering him susceptible to this rather mildly virulent infection.

In the light of modern nutrition studies we have come to regard as unsatisfactory some of the diets widely used by man. We have demonstrated in certain respects that there is a close parallelism between the history of a poorly nourished animal and a poorly nourished man. Much remains to be learned of the finer details of the dietary habits of man in various parts of the world, and of the health conditions with which these can possibly be correlated. It has seemed, however, that we have succeeded in correlating certain data relating to human nutrition with the results of laboratory studies in a manner which brings to light a most important principle in the selection of foods. If these deductions are sound it is evident one of the great tasks of the general undertaking of raising the standard of public health is the education of the public along two lines. One of these is to extend the use of dairy products, and the other is the cultivation of the habit of eating much more freely of green leafy vegetables than is now the practice anywhere in the United States.

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THE RELATION OF THE U. S. NAVAL OBSERVATORY TO THE NAVY AND SHIPPING INTERESTS OF THE COUNTRY.*

BY

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When a sailor comes into the open he casts an eye aloft and scans the heavens, not only to form an estimate of the seeing and probable weather conditions, but also to note the positions of the heavenly bodies. From this glance he gets an estimate of the course his ship is steering and the possibility of obtaining sights to locate her position on the ocean.

A good navigator, by constantly watching the heavens and consulting his almanac, carries in his head the best times to get his observations of the sun, and just what other heavenly bodies will be in position to be observed at twilight or when the moon is sufficiently bright to light up the horizon distinctly. When cloudy and observations are badly needed, the accomplished seaman knows at once, when a star shows up sufficiently to be observed, what star it is and what use can be made of a snap-shot taken of it with his sextant.

When the navigator gets his observations he notes the conditions under which they are taken and decides mentally on the amount of confidence he will place in them. But when he picks some figures out of his Nautical Almanac with which to work out these observations it never occurs to him to question the accuracy of the tables, nor to question the wireless time signals which he uses to determine his longitude, and which he receives from the Naval Observatory through Arlington by radio practically every day, if he is within three or four thousand miles of Washington.

It is astronomers who furnish the basis of these aids to navigation, and the sailor's confidence in them and their results is complete.

This confidence, while flattering to astronomers and computers, has its drawbacks in that the public is prone to believe that

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the practical results of astronomy are free gifts from heaven, requiring little or no labor on the part of man to keep them up to date.

Astronomy is not only the oldest of sciences, but the father of all sciences, for it was from Astronomy that man first learned of the existence of law in nature which is the basis of scientific progress, and from that knowledge was led to turn his attention to other and nearer phenomena, believing that they, too, must be governed by law.

By watching the heavens through centuries man was gradually impressed with the harmony of motion of the heavenly bodies and the regular recurrence of celestial phenomena.

The risings and settings of the sun, the phases of the moon, the periodic positions of the planets, and the recurrence of the seasons gave food for thought and led to the discovery of rules for the prediction of these phenomena.

Then came Newton's discovery of the universal law of gravitation, which, applied to the observations of the positions of the bodies of the solar system obtained in the past, enabled predictions of their future positions to be made.

Although the laws of gravitation as announced by Newton have stood the test of time, we must not forget the multiplicity of conditions existing because of the number of bodies in space, and the difficulty of obtaining accurate observations.

It is marvellous that observations so accurate can be made from a rotating earth, revolving around the sun, which, with the whole solar system and the so-called fixed stars are themselves rushing through space with great velocities.

But these complications necessitate constant and improving observations, which, in turn, lead to more accurate equations and tables.

The principal practical applications of these tables are in the determination of time, of positions at sea, and in the determination of primary positions on the earth for use in making maps and charts.

These practical applications of astronomy are so essential to a seafaring people that countries having large shipping interests have sooner or later established government observatories to make the fundamental observations, and offices to compute and publish the tables in form for the use of sailors.

Congressional action for instituting a national observatory in this country originated in the earliest movement for establishing a first meridian in the United States, and a report was made by a select committee in the House of Representatives, March 28, 1810, which reported the following resolution: "That it is expedient to make provision by law, authorizing the President of the United States to cause the longitude of the city of Washington from the Observatory at Greenwich to be ascertained with the greatest degree of accuracy, and, for that purpose, to procure the necessary astronomical instruments."

This resolution was laid on the table, and a bill accompanying the report of another select committee was probably destroyed in the burning of the records of the Capitol in 1814. This committee had reported in January, 1813—"that, in their opinion, astronomical observations are highly useful to a navigating and commercial people."

Though numerous scientific reasons were presented to Congress from time to time urging the establishment of a National Observatory, the practical uses of an Astronomical Observatory were not put on record until the Secretary of the Navy, in a letter to the Chairman of the Committee on Naval Affairs of the House of Representatives, dated March, 18, 1830, stated "an Astronomical Observatory "——" would furnish the means of making such observations as would enable astronomers to ascertain or calculate the positions of the heavenly bodies at any time, without being dependent on other nations for the same; and would be, moreover, a fixed point to whose meridian——terrestrial objects may, with certainty, be referred, as far as respects their longitudes," and Commodore John Rodgers, in a letter of the same date to the Secretary, stated as one of the principal objects of an observatory —"to furnish annually our naval and commercial interests with a correct ephemeris, upon the accuracy of which depends so much the safety of our commerce and the lives of our seamen."

In 1830, the Navy established a bureau in Washington for the care of the instruments, charts, etc., of the Navy, and Lieutenant Goldsborough, who had charge, collected the navigation outfits of the Navy there.

About the same time the Navy Commissioners in a letter to the Secretary wrote: "As a matter of national pride and independence, it would be desirable to have an American Nautical Al-

manac adapted to a first meridian of our own— an almanac of this kind would be one of the first fruits of an Observatory, should Congress deem it expedient to establish one."

The necessity for careful rating of the chronometers for the

U. S. Naval Observatory. 26-inch equatorial.

Navy led to the acquisition of a transit instrument to determine the time, and Lieutenant Goldsborough then erected the first astronomical instrument for the Navy at Washington.

Lieutenant Wilkes, who succeeded in charge of the depot in 1833, removed the office to Capitol Hill, and here erected, at his

own expense, an Observatory, sixteen feet square, in which was mounted a five-foot transit loaned by the Coast Survey.

In the spring of 1837 Lieutenant Gilliss was placed in charge of the depot, and, under instructions from Secretary Paulding, commenced a series of astronomical observations of moon culminations, occultations and eclipses, which, with similar observations, to be made by Mr. William C. Bond at Boston, were to be used in determining differences of longitude in connection with the Exploring Expedition to the South Seas under Lieutenant Wilkes.

Gilliss not only succeeded in obtaining some necessary astronomical instruments, but persuaded the Secretary of the Navy to authorize the purchase of magnetic and meteorological instruments and to order additional assistants for the work at the depot.

Under these instructions of the Secretary of the Navy, Lieutenant Gilliss of the United States Navy, himself made most of the astronomical observations and was "the first in the United States who conducted a working observatory, and the first who gave his whole time to practical astronomical work; it was he who first published a volume of observations, first prepared a catalogue of stars, and planned and carried into effect the construction of a working observatory as contrasted with one intended chiefly for purposes of instruction——."

As the observations progressed and the usefulness of the depot to the navigational outfit of the Navy increased the necessity for suitable buildings became more and more apparent, and the practical work already accomplished by Gilliss being gradually brought to the attention of Congress, he succeeded, with the backing of the Navy Commissioners and the Secretary, in getting Congress to pass "an Act to authorize the construction of a depot for charts and instruments of the Navy of the United States," which was approved August 31, 1842.

The report of the Naval Committee which accompanied this bill said, in reference to the value of such a depot: "Since its organization, the Navy has not only been furnished with better instruments and more recent charts, at a greatly less original cost than before, but greater care has been observed in their use, consequent upon the regulations of the Depot, making the masters

of our public vessels directly responsible for each article delivered to them.

"Prior to that time, chronometers were purchased as the wants of a ship or the judgment of a commander dictated, without trial or examination, the only guarantee of its value being the word of the seller. Sextants which were rejected by experienced judges and left as shop-keepers, too frequently found their way into the Navy, through the inability of navy-agents and store-keepers to discriminate between good and bad. A ship rarely went to sea without having the master's store-room half filled with wood compasses, from the prejudice that a light compass could only be obtained by making the bowl of that material. As a necessary consequence, the same set of instruments rarely went to sea two cruises. When the ship returned, they were tumbled into the Navy store, chronometers and all, where they remained till the fitting of a new ship would find them unworthy of further use. This no longer exists; Navy store-keepers are required to render a monthly report of every instrument in their charge; and, as before stated, masters are held directly accountable, so that, with a little additional repair at the end of each cruise, the same set lasts many years. The saving, from this cause alone, is more than the annual cost of the whole establishment."

In reference to Astronomy, the committee say:

"In the summer of 1838, the honorable Secretary of the Navy directed the Superintendent to make a constant series of observations in astronomy, magnetism, and meteorology, ordering an additional number of assistants, and granting authority for the purchase of all necessary instruments."

"We are indebted to other nations for the data which enable our ships to cross the ocean. Not only has the Navy failed to contribute to the common stock from which all our navigators borrow, but our country has never yet published an observation of a celestial body which bore the impress 'by authority'; and it is believed that, until the observations before alluded to in this report, none have ever been directed by the Government which can be considered continuous.

"That great errors exist in the tabulated places of the heavenly bodies, the labors of astronomers of the present day sufficiently prove. Indeed, all who were at all curious in such matters could not have failed to remark how great a difference there was

between the observed and computed times of the last annular eclipse visible in the United States."

"Observatories, though not expensive, cannot prosper in our country until we can obtain rest from the pursuit of mercantile affairs, or their charge is undertaken by the Government. The duties are confining; if properly executed, arduous: and but few are qualified by experience or habits to undertake them. If officers can be found with taste for such duties, an Observatory will give more information to the world, under a military organization, in one year, than under any other direction in two."

"The subject of Magnetism is scarcely less important to the Navy than astronomy. Without a knowledge of the variation of the compass, none but coasting-craft dare venture beyond the precincts of a harbor; yet how few have more than a practical knowledge of the mode of determining its amount. The daily changes of the variation, its extraordinary fluctuations during auroras, the causes, amounts, and modes of correcting the local attraction of ships, and, indeed, the laws governing magnetized bodies generally, are mysteries with which a large portion of the officers have had neither means nor opportunities to become acquainted. Great complaints are made that chronometers perform badly; that ships have been influenced by currents when, if the true cause could be ascertained, it would be found to consist in having steered a wrong course, no allowance being made for local attraction."

"There can be no doubt a large number of the wrecks of shipping occur solely from this cause."

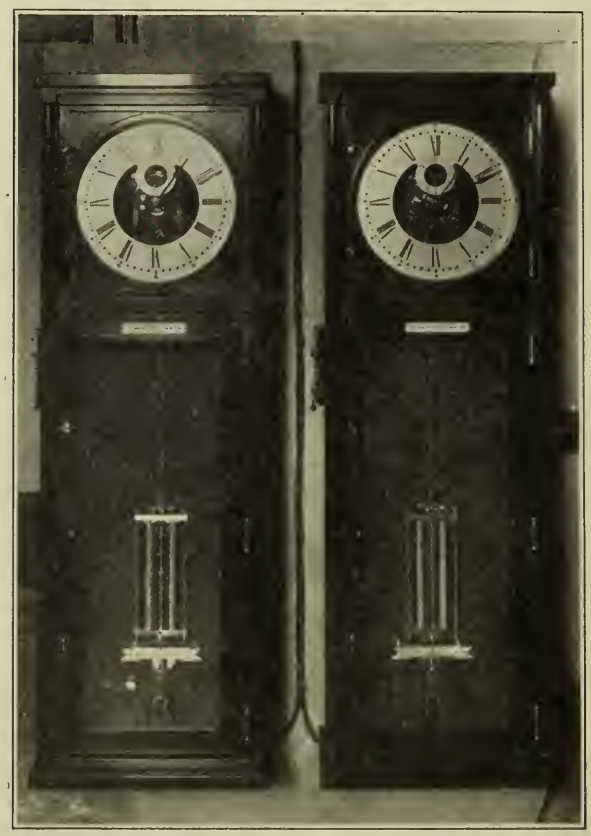
"The magnetic observatories which were established by the European governments two years since, and which have a location in almost every part of the world, were earnestly recommended to us by the learned men of England. Active and extensive co-operation, they say, will be the only mode of setting at rest the conflicting theories of this most important branch of science."

"In regard to Meteorology, if Professor Espy's theory is correct, the day is not distant when we shall be able to calculate the precise point where a storm is raging."

"Meteorological observations are more important at night than by day, because of their scarcity hitherto; and it is scarcely to be expected that amateurs can be found in sufficient numbers to

make all the required observations. Night-watching in stormy weather finds few followers, and we can only hope to obtain the desired information, when those engaged in its pursuit have duty to compel a flagging inclination."

"Deeming an establishment of this description essential to



U. S. Naval Observatory. Transmitting clocks which automatically send out the time signals.

the welfare of the Navy, the committee report the accompanying bill."

A separate report of a select committee on memorials presented by citizens of Philadelphia, New York and Baltimore stated: "——It is incumbent on Congress to provide for the safety of our mariners and of the immense treasures which the enterprise of our merchants throw daily upon the waters.

It is by celestial observations only that charts can be accurately projected——"

The passage of this act in 1842, marks Congressional approval of the Naval Observatory, though it was first called the Depot of Charts and Instruments, and later the Hydrographical Office. In the volume of astronomical observations for 1848, the institution first bears the name of United States Naval Observatory in place of National, by order of the Secretary of the Navy, because the Institution had always been under the control of the Navy Department, and was conducted by Navy Officers, "its reputation is the property of the Navy."

In the act of Congress of March 3, 1849, in appropriating the expenses of the Hydrographical Office it was "Provided that a competent officer of the Navy, not below the grade of lieutenant, be charged with the duty of preparing the Nautical Almanac for publication, and that the Secretary of the Navy may, when, in his opinion, the interests of navigation would be promoted thereby, cause any nautical works, that may, from time to time, be published by the Hydrographical Office, to be sold at cost——."

From and since the Act of Congress of August 5, 1854, specific appropriations have been made for the American Nautical Almanac, and the Revised Statutes, Sec. 436, provided that "The Secretary of the Navy may place the supervision of the Nautical Almanac in charge of any officer or professor of mathematics in the Navy who is competent for that service——."

Lieutenant Matthew Fontaine Maury, to whom Lieutenant Gilliss turned over the new building for the Observatory (which had been completed under his direction), became Superintendent on October 1, 1844, and held that position until he went South in April, 1861, when he was succeeded by Gilliss, who had meanwhile been promoted to a Captaincy in the Navy.

Maury devoted a great deal of his attention to hydrography and interested the Navy and Merchant Commanders in making and preserving "observations on all parts of the ocean upon winds, currents, the barometer, and air and water thermometer, and upon other phenomena calculated to improve navigation." From these reports and the logs of vessels Maury planned and published wind and current charts, and sailing directions on which are still based our present charts, and which have not only materially shortened the passage along the highways by which

our ocean borne commerce passes, but have enabled shipping to avoid locations where large percentages of bad and unfavorable weather conditions are found.

Gilliss, who was a practical astronomer and who had said in his report in 1845, that "he would have regarded his time as misspent to labor so earnestly only to establish a depot of charts and instruments; that his aim was to place an institution under the management of Naval officers, where, in the practical pursuit of the highest known branch of science, they would compel an acknowledgement of abilities hitherto withheld from the service," built up the astronomical staff of the Observatory and acquired new instruments during his Superintendency lasting until his sudden death February 9, 1865.

The Naval Observatory at this time included an Astronomical Observatory, a Hydrographical Office, a Depot of Charts and Instruments, a Meteorological and Magnetic Observatory, and the Superintendent was even required to make a report on interoceanic canals and railroads under the resolution of the United States Senate of March 19, 1866—"Resolved, that the Secretary of the Navy furnish, through a report of the Superintendent of the Naval Observatory, the summit-levels and distances by survey of the various proposed lines for interoceanic canals and railroads between the waters of the Atlantic and Pacific Oceans, as also their relative merits as practicable lines for the construction of a ship canal and especially as relates to Honduras, Tehauntepec, Nicaragua, Panama, and Atrato lines."

These were too diverse activities for a single institution and Congress, by its Act of June 21, 1866, established the United States Hydrographic Office, which then took over the hydrographic work which the Observatory had started.

In 1880 Congress appropriated funds for the purchase of a new site and the preparation of plans for new buildings for the Naval Observatory, and in 1886 the funds for the buildings.

Under these appropriations the site for the present Observatory was carefully selected with a view to its fitness for mounting astronomical instruments and observing with them, and at the same time to be accessible from the city of Washington, and the buildings were carefully designed to suit its needs.

Upon the completion and acceptance of the new buildings on Georgetown Heights the Naval Observatory was moved

there in 1893, and at the same time the Nautical Almanac Office with its library was transferred to and made a department of the Observatory.

In order to give very briefly the reasons for the establishment of the Naval Observatory and the American Nautical Almanac and to afford time in which to tell of the practical assistance they now afford our Navy and Merchant shipping, I have been obliged to leave out practically any account of the work of the many distinguished men who have been connected with their activities.

I must, however, mention, in addition to Gilliss and Maury, the names of Goldsborough, Wilkes, Charles Henry Davis, father and son, John Rodgers, Asaph Hall and Simon Newcomb, of the Navy, and George William Hill, all of whose names are well known to science, but an account of whose work it would take up too much time to attempt to give now.

THE WORK OF THE NAVAL OBSERVATORY.

The first object in acquiring an astronomical instrument for the Depot of Charts and Instruments was for the correct determination of time in order to find the errors and rates of the Navy chronometers.

This service has been continued ever since, and has expanded until now the Naval Observatory not only furnishes accurate time by radio, twice each day, via the Navy radio station at Arlington (and other Navy radio stations when desirable), to vessels anywhere within three or four thousand miles of Washington, and to thousands of private parties who have set up receiving sets throughout the country; but also puts the time signal on any telegraph or telephone wires which are run to the Observatory for the purpose of receiving it.

This has resulted in the Western Union Telegraph Co. supplying Naval Observatory time wherever their wires are run. West of the Rocky Mountains the time signals originate at the Navy Chronometer and Time Station maintained at the Mare Island Navy Yard.

The benefit of standard time signals to the shipping and inland transportation interests of this country, and to watchmakers, jewelers and persons engaged in scientific and other pursuits requiring accurate time, not to mention the general public, is so tremendous that it is difficult to conceive of the confusion and

troubles that would arise were this service discontinued even for a few days. It is often amusing to note the surprise of persons who thought they possessed perfect time keepers, when, on making continuous comparisons with an accurate time signal, they find how much their supposedly accurate watches vary from day to day.

To maintain a time service the Naval Observatory keeps up continuous observations, when weather conditions do not prevent, of the passage of so-called clock stars over the meridian of the Observatory, by means of telescopes set permanently in the meridian and provided with suitable mechanism for accurately determining the time of passage of the stars. These times are compared by means of chronographs with standard clocks whose errors are thus determined whenever a set of stars is observed. The standard clocks are not only the most accurate clocks made, having pendulums of invar, which practically does not expand or contract, but they are secured to solid piers set so far in the earth as to avoid all tremors or vibrations short of those occasioned by earthquakes, and are in a vault where the temperature is maintained constant within one-tenth of a degree Fahrenheit. Each clock is sealed in a glass case and the air partially exhausted so that the resistance of the air and its moisture content is kept constant. They are wound by electricity.

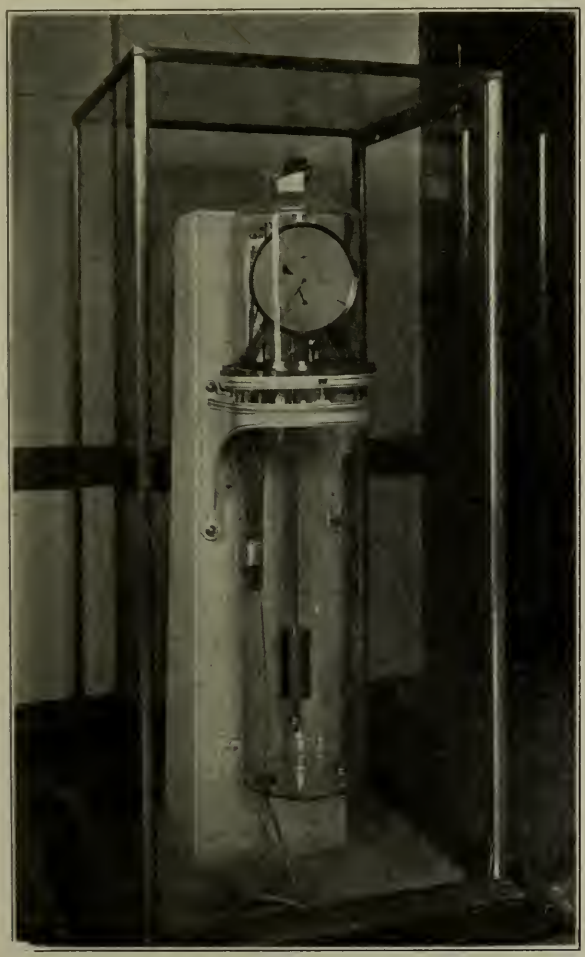
Through electric connections the reading of any one of the three standard clocks is communicated throughout the Observatory and can be compared on chronographs with any other time keeper, star or other observation.

In order to transmit the time signal at noon and 10 P.M., two auxiliary clocks made for the purpose are used, so that having set one of these clocks correctly by comparison with the standard clock shortly before the time for the signal, the clock automatically transmits the signals to as many electric relays as may be desired. The actual time of this signal at different places is checked back from time to time, and the lag, as it is called, at Arlington, is within .01 second of time, and, at Key West, due to the signal being several times relayed by land wire, averages .28 second.

The number of the private radios receiving time was hardly appreciated by the Observatory until they were shut down by the war, and the usefulness of them to the public was emphasized

by the number of immediate requests for permission for their rëestablishment as soon as peace conditions prevailed.

Of course during the war the time signals went out by Navy



U. S. Naval Observatory. Standard clock, three of which are kept at a constant temperature and pressure in an underground vault. These clocks are wound by electricity, and their beats are transmitted by electricity throughout the Observatory so that the vault does not have to be entered unless in case of emergency.

radio and land lines without intermission, and were so necessary to shipping passing through the submarine zone that all other radio work was stopped while the time signal was being sent.

The determination of time by the transit instruments at the

Naval Observatory is only a small part of the work of the Observers on those instruments, and while these results are more immediately apparent, the real work of the instrument is in the determination of the absolute positions of the heavenly bodies.

These positions are ultimately used, not only for time determination, but for navigational and astronomical work.

The astronomical work of the Naval Observatory is planned and executed, "To furnish to the Nautical Almanac Office, as far as possible such observations and such data as may be needed for carrying out the purpose of the law under which the appropriations for that office are made from year to year, which is as follows:

"For——preparing for publication the American Ephemeris and Nautical Almanac and improving the tables of the planets, moon, and stars."

The principal astronomical work of the Observatory is in the field of the astronomy of position as distinguished from astrophysical work, and is the continued maintenance of observations for absolute positions of the fundamental stars and of stars which are to be made fundamental, and in addition the independent determination by observations of the sun, of the position of the ecliptic, and of the equator among the stars, and of the positions of the stars, moon, and planets with reference to the equator and equinoxes.

For carrying out this plan of work the principal instrumental equipment of the Observatory consists of a 9-inch and a 6-inch transit circle, a prime vertical transit instrument, an alt-azimuth, a photographic zenith tube (for the determination of the variation of latitude), a 26-inch and a 12-inch equatorial, a photographic telescope, and a photoheliograph, besides the necessary chronographs and clocks and a clock vault where the standard clocks are kept at a constant temperature. The handling, lighting, and recording of these instruments requires an electrical equipment of motor generators, storage batteries, switchboards, and thermostats and fans, and the mechanical equipment for opening and closing shutters, turning domes and raising the floor of the large equatorial is considerable and requires constant attention. All of these instruments are in actual use now, excepting the prime vertical transit with which a series of observations, continuous for 19 years, has lately been completed.

In order that the work of computing and publishing the observations, without which they are valueless, may keep pace with the observational work there is a small computing division which assists the observers on the instruments in reducing their work; and, incidentally, furnishes a try-out for the young men who first come to the Observatory, and a source from which to draw for observers. Fortunately for Astronomy, it is such an absorbing science that those really devoted to it are almost indifferent to their own material welfare, and work night and day in cold and heat, with sleep and meals at irregular intervals, on a mere pittance. If it were not for this devotion to Astronomy on the part of a few men it would be impossible to get any one to do the work of the Observatory on the salaries allowed by the Government.

These men, because of their knowledge of instruments, optics and glass, were tremendously valuable to the Navy at the outbreak of the war, because of our previous dependence on foreign countries, particularly Germany, for these things, and the necessity for having advisers for the firms undertaking to provide us with glass and instruments made in the United States.

THE NAUTICAL ALMANAC OFFICE

Fortunately Congress in 1912 in authorizing the Secretary of the Navy to arrange for the exchange of data with such foreign almanac offices as he might from time to time deem desirable, with a view to reducing the amount of duplication of work in preparing the different national nautical and astronomical almanacs, and increasing the total data which may be of use to navigators and astronomers available for publication in the American Ephemeris and Nautical Almanac, "Provided, further, that the work of the Nautical Almanac Office during the continuance of any such arrangement shall be conducted so that in case of emergency the entire portion of the work intended for the use of navigators may be computed by the force employed by that office, and without any foreign coöperation whatsoever."

This saving clause enabled the Nautical Almanac to be published as usual, notwithstanding the war, and from 1300 Ephemerides and 1165 Nautical Almanacs for the year 1916, the numbers of the 1918 volume required increased to 1597 copies of the American Ephemeris and 5153 copies of the Nautical Almanac.

These increases were principally due to the increase of our shipping, both naval and mercantile; but the War Department required 845 copies of the American Ephemeris and 535 copies of the Almanac, and of these the American Expeditionary Forces in Europe took 500 copies of the American Ephemeris for strictly military work.

The Departments of Agriculture, Commerce, Interior, and Treasury took 229 copies of the Ephemeris for 1918 and 323 copies of the Almanac.

These publications, besides giving the positions of the sun, moon, planets and stars, give the celestial phenomena for the year, such as eclipses, occulations, etc., tables for the use of navigators and astronomers for converting time and for finding the latitude by an observed altitude of Polaris; and the times of sunrise and sunset and moonrise and moonset, the value of which not only in war but to the average citizen and to light and power companies is obvious.

NAVIGATIONAL INSTRUMENTS

The Naval Observatory is charged with the development, supply, upkeep and inspection of gyro and magnetic compasses, compass equipment, chronometers, clocks, watches, sextants, sounding apparatus, spy glasses, binoculars, and in fact all navigational and meteorological instruments used by the Navy, not only for its surface craft, but for submarines and aircraft.

Prior to the war, the increasing speed and draft of surface vessels, increased gun ranges, and the development of underwater and air craft necessitated new and improved instruments and methods for accurate and rapid navigational and plotting work. The Naval Observatory had encouraged suggestions and the development of methods and instruments, sending out to the service for trial all that gave promise of usefulness.

Special efforts had been made to interest American firms in the manufacture of chronometers, torpedo boat watches and timekeepers in general, of sufficient accuracy to pass the Observatory tests.

Still the number of any one kind of navigational instrument required by the Navy was not great; our merchant marine required but few, and so the manufacture of nautical instruments in this country was confined to a few firms of limited capacity.

Although some chronometers were assembled in this country, the chronometer parts and all torpedo boat watches were manufactured abroad, and practically all optical glass was imported. However, the possibility of American firms undertaking to substitute their products for imported ones had been thoroughly gone into, and where it had not been undertaken it was due to the fact that the American firms did not believe it could be done at a profit, principally because of the limited demand for nautical instruments.

Fortunately the Naval Observatory had encouraged the development of a compass in this country which was not influenced by the magnetic materials of the ships, and a number of these gyro compasses were in use on the dreadnaughts and submarines of our Navy.

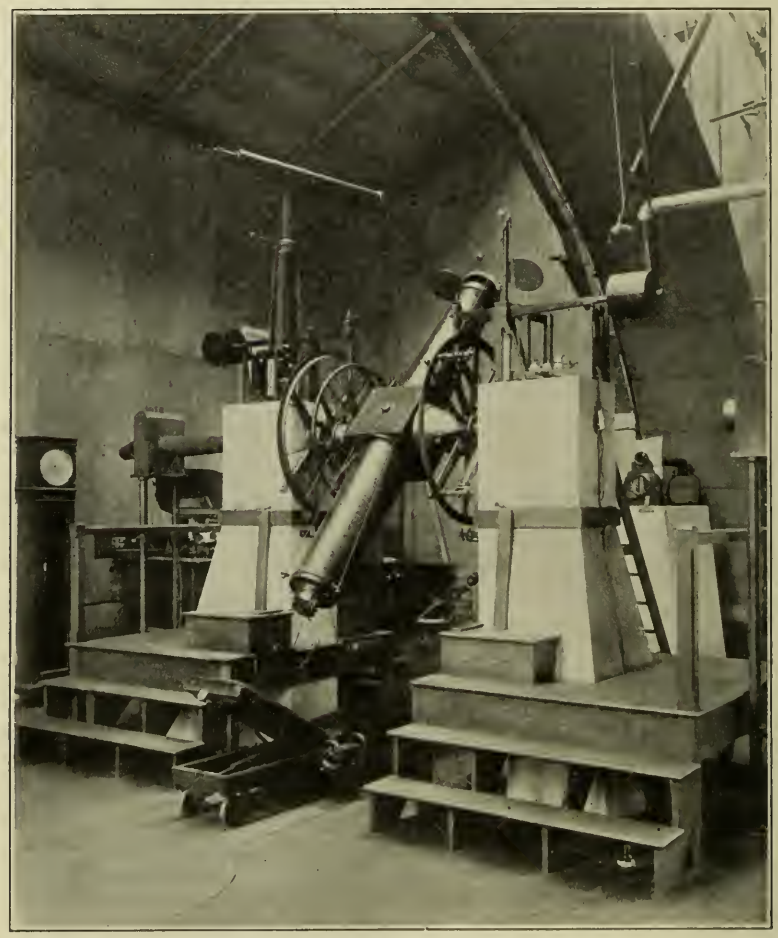
The want of sufficient directive force, the necessity of its installation in an exposed position, the inaccuracies due to movements of large masses of steel (such as turrets and guns), and the practical difficulties in the way of transmitting the readings of the magnetic compass to other points had made it extremely desirable to provide a compass much superior in these respects, at least, to the magnetic compass for battleships, while for the submarine a magnetic compass confined within a steel shell was practically useless. The development of the gyro compass had also been aided by the demand for it, before our entry into the war, by the countries allied against Germany; and as, outside of Germany, America had produced the only gyro compass, the demand for it became very great.

While the Navy had but few aircraft prior to our entry into the war, the necessity for navigational and meteorological instruments for aircraft had been recognized, and the Observatory was encouraging and taking part in their development.

Still all this preliminary work, because of the limited demand in this country, and the small amount of money available by the Navy for development work, furnished only a part of the foundation for the increase required when we entered the war. But attention had been directed to our possible requirements and there were a number of people who had spent considerable thought over them and who were prepared to assist commercial firms in developing into makers of navigational instruments.

A few years before the war the repairing of navigational in-

struments by outside contract was so unsatisfactory, not only in regard to cost but in the time taken and the impractibility of getting the contractors to distinguish between urgent jobs and those that could be delayed, that the Naval Observatory started a repair



U. S. Naval Observatory. 9-inch transit circle.

shop and got an appropriation for furnishing a suitable building in which to locate the shop.

During the war this shop was invaluable not only for the work it turned out, but because the foreman and mechanics were in a position to advise firms undertaking work that was new to them

as to the machinery necessary for their plants and the qualifications of their mechanics.

As the war progressed the Naval Observatory found that it not only had to supply a tremendously enlarged Navy, but vessels taken over from the merchant marine for transports and freight carriers, and finally the vessels built by the Shipping Board.

The latter has helped to prevent waste, loss to contractors and an undue accumulation of a surplus of instruments contracted for before the armistice was signed by taking them over for their shipping which is still being turned out in large numbers.

One of the most urgent needs of shipping plying in the submarine zone was for large numbers of binoculars and other glasses, in order that the lookouts, whose numbers were greatly increased over those required in times of peace, might pick up and distinguish suspicious objects promptly. To meet this demand a call was made on the citizens of the country by the Assistant Secretary of the Navy, Mr. Roosevelt, to loan their glasses, and any navigational instruments they might have, to the Navy for the duration of the war. The response from patriotic citizens was so enthusiastic that 32,000 serviceable pairs of glasses were received, and those that could be were issued and used. They have practically all been returned to the owners with suitable acknowledgment.

THE LIBRARY

One of the features of the Naval Observatory that deserves mention is the library, which is believed to be the most complete mathematical and astronomical library in the world.

The books are not only constantly used by the astronomers of the Observatory but by others engaged in mathematical and astronomical research.

ECLIPSES

In checking up the positions of the sun and moon, solar eclipses furnish a means of verifying their relative positions by marking the times of contact, and for this purpose the Naval Observatory has sent out a number of eclipse expeditions, and at the same time has taken advantage of them to make photographs of the sun's corona and to afford opportunities for spectroscopic observations of it.

DETERMINATIONS OF DIFFERENCES OF LONGITUDE

The Naval Observatory has taken part in or assisted with a number of determinations of differences of longitude; and, in the winter of 1913-14 made a determination of the difference of longitude between Washington and Paris, using radio signals between the Navy Radio Station at Arlington, Virginia, and the Eiffel Tower at Paris.

This work was done in duplicate by observers from the Naval Observatory and by the French, but owing to the war, the computation of the French results was delayed so that the Naval Observatory published the first transatlantic radio determination which was also the first trans-Atlantic determination without intermediate stations.

The distance between Washington and Paris is 3830 miles and radio had never previously been used for longitude determinations at a distance exceeding 960 miles.

When the French results were obtained they were found to agree very closely with those of the Observatory, differing only by two thousandths of a second of time, making the determination of great accuracy.

DISCOVERY

While the principal observational work of the Observatory is in the field of astronomy of position as distinguished from astrophysical work and discovery, the satellites of Mars were discovered by Prof. Asaph Hall of the Navy with the 26-inch Equatorial, and other minor discoveries have been made.

FACILITIES FOR THE PUBLIC

In order to afford the general public a view of the heavens the 12-inch equatorial is given over to their use one evening in each week, cards of admission being issued, and the Astronomer, in charge, besides showing celestial objects, gives a short talk on popular astronomy.

SUMMARY

To sum up, the Naval Observatory performs four principal functions, which are not only absolutely necessary to the Navy and Shipping interests of this country but to the country at large. These functions have been developed by the Navy as the needs for them have arisen, and the plant has been pro-

vided by Congress upon the representations of and work done by the Navy.

These functions are:

(*a*) The furnishing and transmission of daily time signals both by radio and telegraph.

(*b*) The computing and preparing for publication of the American Ephemeris and Nautical Almanac and the Nautical Almanac.

(*c*) The continuous maintenance of observations for absolute positions of the fundamental stars, and the independent determination by observations of the sun, of the position of the ecliptic, and of the equator among the stars, and of the positions of the stars, moon, and planets with reference to the equator and equinoxes in order to furnish data to assist in preparing the American Ephemeris and Nautical Almanac and improving the tables of the planets, moon, and stars. At the same time this department furnishes the observations for determining the time.

(*d*) The development, supply, upkeep and inspection of all navigational instruments for the Navy, which incidentally the Observatory has practically done for the Shipping Board, and has established standards for the growing merchant marine of the country.

The Naval Observatory started the development of the Hydrographic Office; made the first systematic meteorological and magnetic observations at the Capital; and has lately fostered the development, amongst many other instruments, of those necessary for the navigation of submarines and air craft.

Alcohol from Wood. (*Chemical Age,* vol. ii, 1920, 329.)—The production of ethyl alcohol from wood has long been a matter of investigation. The vast amount of wood-waste, for which but little use is made other than for fuel has made the question one of great practical importance. That cellulose, the most characteristic proximate principle of wood, is of the same type as starch and sugar and capable of conversion into a fermentable carbohydrate, dextrose, commonly called glucose, has long been known. In the article from which this abstract is being made, F. W. Kressman gives a great deal of interesting information and presents the practical side of the utilization of wood as a source of ethyl alcohol. As a preliminary he gives some data in regard to

the cost of alcohol from other sources. A bushel of maize yields about 2.4 United States gallons of 95 per cent. alcohol, and a residuum of about 15 pounds of distillers' grains, having a value equal to or even greater than that of the original grain. Molasses yields per gallon rather less than half a gallon of 95 per cent. alcohol. Recently, because of high sugar prices, the sugar content of molasses has been stripped more closely and the yield of alcohol will be diminished.

The production of ethyl alcohol from wood is based upon the hydrolytic effect of dilute acid on cellulose. Kressman gives the cost of grain alcohol before the war as from 10 to 17 cents per gallon, and from molasses somewhat less. These figures seem a little low, but at any rate, present prices are decidedly higher, alcohol from grain costing about 22 cents per gallon and from molasses about 18 cents. Coniferous woods will generally yield from 12 to 20 gallons of 95 per cent. alcohol per ton of dry wood, and coniferous wood-waste about the same amount. The production of commercial alcohol from corn is now practically stopped with corn at $1 per bushel.

The first step in the process of obtaining alcohol from wood is digestion at a pressure of 115 pounds for fifteen minutes in a little less than 2 per cent. of H_2SO_4 per 100 pounds of dry wood, the acid being largely diluted, of course, to avoid carbonization. The cooked wood resembles coffee grounds and the mass contains the sugars. It is transferred to the "diffusion battery," which consists of a series of cylindrical cells so connected that water may be passed through them in rotation. From these cells an extract called "acid juice" is obtained which holds in solution practically all the sugar mixed with other water-soluble ingredients. This liquid is neutralized, either with high-grade limestone or slaked lime. Calcium sulphate is produced which requires about twelve hours for settling. The clear juice is drawn off and cooled to about 88° F., yeast added, and the fermentation carried on in the usual way. The juice must be slightly acid, as ordinary yeasts do not function well in alkaline solutions. By distillation the alcohol is obtained and may be readily refined to the grade of cologne spirit by well-known methods.

Kressman figures that the manufacturing expense, excluding office and sales expense, and package costs, also, unless goods are shipped in tank cars, will be about 21.5 cents per gallon. In some cases, as when coniferous woods are used, turpentine and other by-products may be obtained which will reduce the net cost. The acid juice contains a considerable amount of carbohydrates not ordinarily fermentable, and investigations into these are in progress. Lastly, it is stated that under present conditions the processes can be conducted with profit only in rather large plants.

H. L.

AN AERODYNAMICAL TORSION BALANCE.*

BY

A. F. ZAHM, Ph.D.

Bureau of Construction and Repair, U. S. N.

It frequently has been found necessary to determine the torque of aerodynamic models about a single axis, or to find the axis of zero torque. To effect this rapidly and accurately the torsion balance described in the following paragraph was developed:

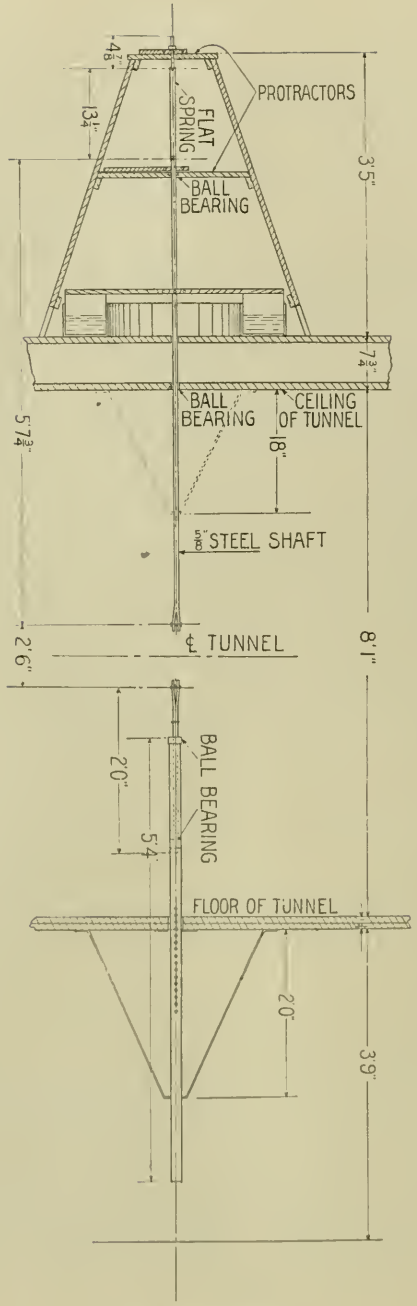
As shown in Fig. 1, the instrument consists of a vertical steel spindle rod supported from a torsion head by means of a thin steel ribbon and steadied in at least two places by ball bearings, the lower end of the shaft terminating a short distance above the centre of the wind tunnel in which the models are to be tested.

The supporting stand resting on the floor above the tunnel, as shown in Fig. 2, carries two horizontal graduated circles coaxial with the spindle, one just above the ribbon, the other just below. A pointer fixed to the spindle and playing over the lower circle shows the angular position of the model with respect to the wind direction; another pointer fixed to the torsion head and playing about the upper circle measures the angular distortion of the steel ribbon by comparison of its orientation with that of the lower pointer. This top pointer rests with considerable friction on the upper graduated circle and forms part of the torsion head from which depends the total weight of the spindle and model. Resting on the floor and coaxial with the spindle is a sheet metal dash-pot containing oil or water and serving to damp the vibration of the torsion rod by means of paddles shown fixed thereto. Supported from the tunnel ceiling is a removable brace shown in dotted outline which can be used to steady the spindle in case of severe lateral forces tending to bend or shake it.

The apparatus just described is complete in itself and useful for a variety of tests, but for other tests requires the supplementary vertical spindle supported on the floor of the tunnel, as shown in Fig. 1. This supplementary spindle is steadied by two ball bearings inside of a coaxial bracing pipe through which it may be raised or lowered slightly. Sometimes also the two spindles form one continuous rod, as shown in Fig. 3. For a larger

* Communicated by the Author.

FIG. 1.



Torsion balance assembly.

vertical adjustment the outer pipe itself may be raised or lowered and fixed at any height by means of the pin holes and pin shown in the drawing. It is steadied laterally by a closely fitting plate in the floor of the tunnel and a bearing in the metal bracket shown

Fig. 2.

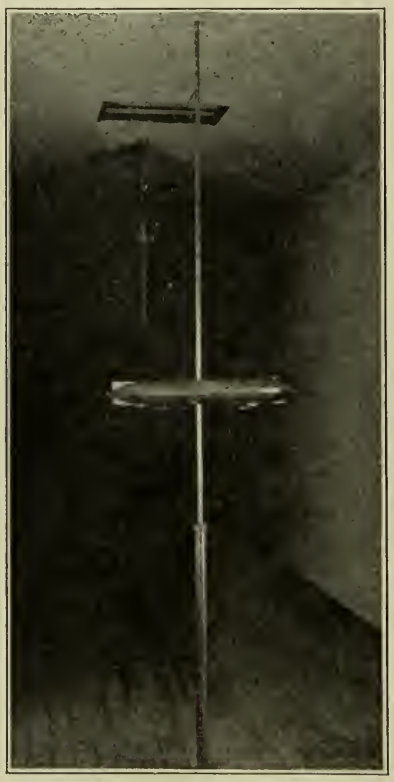
Upper part of torsion balance.

suspended below the floor of the tunnel. When not in use this larger pipe is dropped down so that its top becomes flush with the interior of the tunnel. Both spindles are removed when not in use.

Fig. 4 giving the calibration diagram for the torsion spring, shows that the angular deflections are directly proportional to the

torque, according to Hooke's Law. The calibration was effected by means of suitable weights and a fine cord running about a grooved disc on the lower end of the spindle. Readings were taken both when the spindle carried a model and when unloaded, and were found practically the same for moderate loads. So long

FIG. 3.



Torsion balance used to measure moment on airship hull.

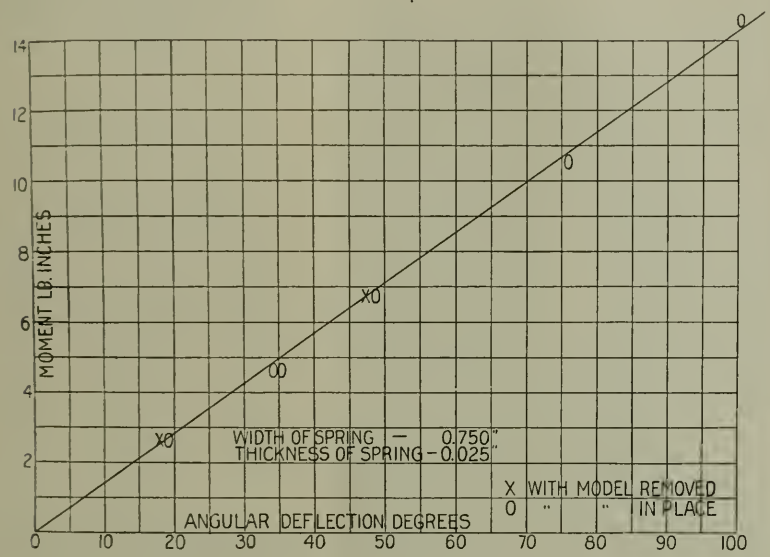
as the axis of the spindle is truly vertical there is no tendency to rotate under gravity even with an eccentric load.

Figs. 3 and 5 illustrate applications of the balance. Fig. 3 shows a Zeppelin balloon model supported on a single vertical spindle and steadied at the upper and lower parts of the tunnel and allowed to assume various angles in yaw. When the model is tested for various angles of pitch it is supported in a similar

manner, but rotated about its own axis 90°. Fig. 5 shows an aerofoil supported at its ends by means of the upper and lower spindles which grip it by means of the forked ends shown, the model itself being capable of displacement up or down stream by means of the narrow strips attached to its ends and clamped by the forks.

In such tests it may be desirable either to determine the axis of no torque or to determine the torque of the model for various

Fig. 4.



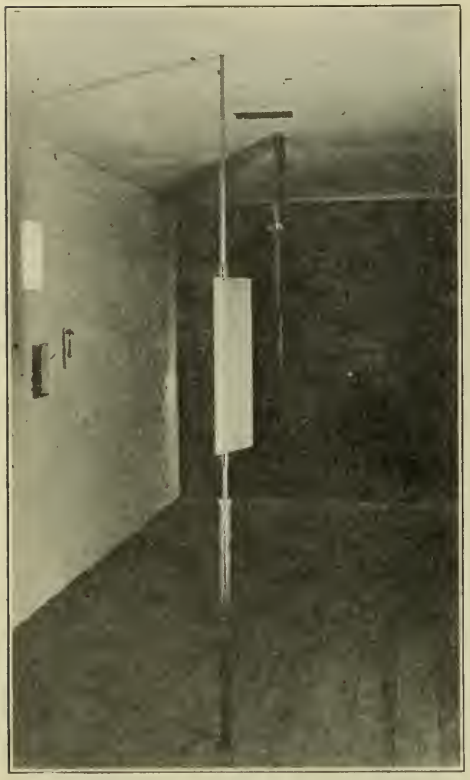
Calibration diagram for spring of torsion balance.

angles of incidence. To determine the axis of no torque the model is allowed to swing freely until it comes to rest in the wind when there is no distortion of the suspension spring, that is, when the torsion head pointer is set exactly parallel with the lower or incidence pointer. To determine the torque of the wind on the model for any particular angle of incidence the torsion pointer is rotated sufficiently to cause the incidence pointer to indicate the chosen angle of incidence. The difference of reading of the two pointers then gives the angular deflection of the ribbon, or the torque by reference to the calibration diagram.

Fig. 6 shows the torsion balance mounted on a wind-tunnel lid, and being transported to its working position on top of the

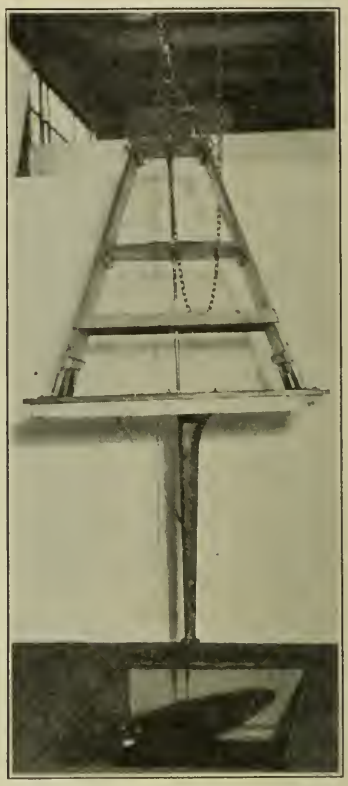
tunnel. When not in use, the instrument and its lid rest on a rack at one side of the laboratory. Models are there attached to the spindle shank and made to swing freely. When the combination is set upon the tunnel, all is ready without further adjustment.

FIG. 5.



Torsion balance used to measure moment on aerofoil.

FIG. 6.



Torsion balance mounted on wind-tunnel lid.

The stream-line hanger shown suspended under the lid carries a ball bearing at its top and bottom to steady the spindle. Two stay wires hold it plumb and prevent trembling. The apparatus is found to be accurate and convenient.

THE PHOTOGRAPHIC RENDERING OF TONE VALUES.

BY

LOYD A. JONES.

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INTRODUCTION.

PHOTOGRAPHY deals with the reproduction of the tone values of the subject in the form of variations of light and shade in the print, each tone in the original subject being represented by a corresponding tone in the finished print, and it is the object of the photographic process to effect a reproduction in which the scale of tones in the finished print corresponds as closely as possible to that of the subject, or in which the scale of tones is modified in a known manner, either from necessity due to the limitations of the process or in order to produce the desired psychological effect. It should be emphasized at this point that the primary object in making a photograph is not in most cases the exact reproduction of the brightness and contrast of the original, but rather the production on a flat surface of variations in reflecting power such that the subjective impression obtained when this surface is viewed under a specified illumination will be as nearly identical as is possible with that produced in the mind of the observer when viewing the objects photographed. In discussing the reproduction, therefore, a careful differentiation should be made between the two phases of the problem, which may for convenience be termed the objective and subjective phases. The former deals with the reproduction of the objective brightness and contrast of the original, such factors being measurable by the usual physical methods of photometry. The latter, dealing with the subjective evaluation of physical brightness and contrast, requires the application of those psycho-physical laws which determine the subjective impression produced by the action of various physical stimuli when applied to an eye in some specified state of sensitiveness or adaptation. This adaptation level is in turn dependent upon the magnitude and time of application of the physical stimuli.

It is proposed in this article to trace the various steps in the photographic process and to explain the factors which affect the objective photographic rendering obtained, the discussion of

the subjective phase being entirely ignored. The factors of importance in tone reproduction may be classified as those dealing with the distribution of light and shade in the subject, the translation of the tones of the subject in the making of the negative including the effect of exposure and development, the scale of printing papers and the translation of the scale of the negative into the scale of the print, and finally the accuracy of the entire reproduction itself, as shown by a direct comparison of the print with the original subject. The last step in this process will be dealt with in a later paper. The present article is intended to form an introduction to the elementary theory of the subject.

THE DISTRIBUTION OF LIGHT AND SHADE IN THE SUBJECT.

When a pictorial representation of a natural object is made upon a flat surface, its form may be represented by areas differing in brightness and color. A painter, for instance, employs both means, while a black and white draughtsman confines himself to differences of brightness, ignoring color. With the exception of special branch of color photography, photography deals only with the reproduction of objects by different gradations of light and shade, and in this article we shall not only ignore the question of reproduction in color but also the fact that natural objects have different colors, and shall consider the problem of their reproduction as if everything consisted of areas differing only in brightness, that is, a series of grays of which black and white are the limiting members. Thus we shall deal with the tone gradations of natural objects but shall ignore the fact that they have also differences of color. The translation of differences of color into monochrome is best considered as a separate branch of photography, which is called "orthochromatic" photography or the photography of colored objects—and it is not proposed to take up this subject in the present article.

Ignoring the question of color, therefore, it is necessary in order to get a precise objective representation of nature to obtain a reproduction as accurate as possible of the whole scale of tones occurring in the scene which is being photographed.

The word "tone" as used in this paper, it should be noted, is practically synonymous with "brightness," being indicative of the intensity factor of the radient flux which, when it falls upon the retina produces the sensation of light. The word "tone" has

been used in some cases to indicate the quality factor (*i.e.*, hue, or saturation), but in the literature of photography its usage has been almost exclusively as indicative of the intensity factor. This precedent seems amply sufficient to warrant its continued use in this sense and hence throughout this paper it should be interpreted as referring to the intensity factor, *i.e.*, brightness. Areas differing in tone, therefore, differ in brightness, or if they are subject to identical illumination they differ in reflecting power and a tone scale consists of a series of areas differing in brightness or in the special case of a flat surface uniformly illuminated of areas differing in deflecting power.

In natural objects these tone gradations are produced by differences both in the reflecting power and in the illumination of the object. The brightness of any portion of a natural object will depend, therefore, upon the illumination falling upon it and also upon its reflecting power. Objects differ very much in reflecting power, the range being from 90 per cent. for white chalk to 1 per cent. for black velvet. The ratio of the highest to the lowest brightness present in any sense may be referred to as the "contrast" of that scene, so that if we have a uniformly illuminated field in which is an area of white chalk reflecting 90 per cent. of the light and also black velvet reflecting only 1 per cent., the contrast will be 90 to 1, or simply 90.

Natural subjects like landscapes may have a greater contrast than this owing to their variation, not only in reflecting power but also in illumination; however, most landscapes have less contrast than the example given. As a result of the measurement of a number of photographic subjects, we may say that a contrast of 4 to 1 would be an extremely short scale or low contrast—a range which would occur in such scenes as the streets of a northern city on a dull day in winter. A scale of 10 to 1 would be a very soft contrast, one of 20 to 1 a soft contrast, while a subject having a scale of 40 to 1 would be considered as a subject of normal contrast. The measurement of contrast in natural subjects such as landscapes can be made by means of a portable illuminometer fitted with a standard lamp and calibrated for the measurement of brightness. By the measurement of the brightness values of a number of natural subjects, the greatest contrast was found in a landscape which included a shadow in a wood and sunlit hills above a river. A total range of 250 to 1 (contrast = 250) was

obtained, the sky being 250 times as bright as the deepest shadow in the wood.

In studio work the contrast is governed largely by the character of the lighting. It was, for example, found by actual measurement that the contrast between a white waist and a black skirt on a sitter, when the lighting was of average quality, was 40 to 1, while the same subject under a softer lighting gave a contrast of 30 to 1. In line lighting the contrast obviously may be very great indeed. In general, in home portraiture, it is difficult to keep the contrast low and at the same time secure lightings pleasing from an artistic standpoint. Measurement showed that typical cases gave a contrast of 65 to 1 on the sitter. When rather dark room furnishings form the background, the contrast between, say, a sitter's waist near the window and the darkest portion of the background may easily be 100 to 1.

THE TRANSLATION OF THE TONES OF THE SUBJECT INTO THE OPACITIES OF THE NEGATIVE.

The purpose of the photographic process is, as has already been mentioned, to reproduce the scale of tones which occurs in the subject photographed as a corresponding scale of tones in the print, and the first step toward accomplishing this is the production of the negative. If this operation does not involve any distortion of the scale of tones, we may say that we have a "technically perfect" negative; and we may define a technically perfect negative as one in which the opacities of the various areas are proportional to the light reflected by the parts of the original subject which they represent.

By the "opacity" of a negative we mean the inverse of the transparency. Thus, if we have light of intensity I falling upon a silver deposit and the deposit transmits an intensity I_1, then we may write

$$\text{Transparency as } T = \frac{I}{I_1}$$

and

$$\text{Opacity, as } O = \frac{1}{T} = \frac{I_1}{I}$$

Now, it can be shown experimentally that the mass of silver per unit area is proportional to the logarithm of O, and it is

customary in photographic work to call this quantity D, the density, so that we have

$$D = \log O = \log \frac{I_1}{I}$$

In practical photographic work the logarithms used are common logarithms so that a density of unity will correspond to an opacity of 10, and a deposit having this density will transmit 1/10 of the light. Similarly, a deposit transmitting 1/100 of the light will have a density of 2, and one transmitting 1/1000 of the light a density of 3. It will readily be seen that when we place two deposits over each other we can find their joint density by adding the separate densities. Thus, if we have one deposit transmitting $1/a$ of the light and another $1/b$ of the light, the corresponding densities will be respectively $\log a$ and $\log b$. When the two deposits are superimposed, they will transmit $1/a \times 1/b$, corresponding to a density of $\log a + \log b$. We see, therefore, that if we have a geometrical series of opacities, we shall have an arithmeti-

FIG. 1.

Reproduction of sensitometric strip.

cal series of densities; and therefore a geometrical series of opacities will correspond to an equal addition of silver for each step since the silver is proportional to the density and not to the opacity.

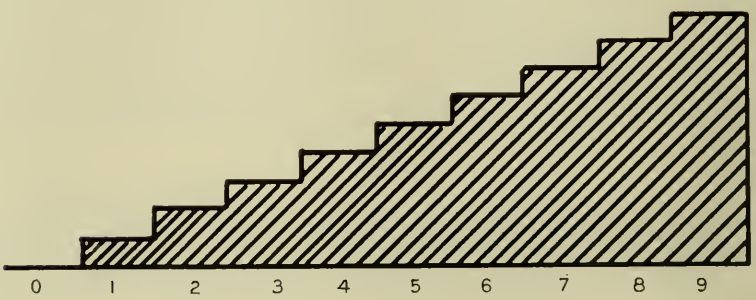
Let us apply this to a photographic example. Take a strip of plate and expose a portion of it to light just long enough to produce on it a barely perceptible blackening after development; then expose another portion for twice the time, another for four times, another for eight times, another for sixteen times, and so on, so that our strip will finally be made up of steps which have received amounts of light in the proportion 1-2-4-8-16-32-64-128-256-512. We might do this by making an instrument which would give different intensities of light in the form of steps and then exposing the plate in this instrument, but in practice it is generally more convenient to give a series of different times

of exposure. Fig. 1 represents the negative we shall get after development.

If the negative correctly represents these different times of exposure in the opacities obtained, the opacities should be in the same numerical ratio as the times of exposure, that is, they should be 1-2-4-8-16-32-64-128-256-512, and since each time the opacity is doubled the density increases by an equal amount, the density (that is, the amount of silver) would be in the proportion 0-1-2-3-4-5-6-7-8-9. as shown in the following table:

Exposures	1	2	4	8	16	32	64	128	256	512
Opacities	1	2	4	8	16	32	64	128	256	512
Densities	0	1	2	3	4	5	6	7	8	9

FIG. 2.



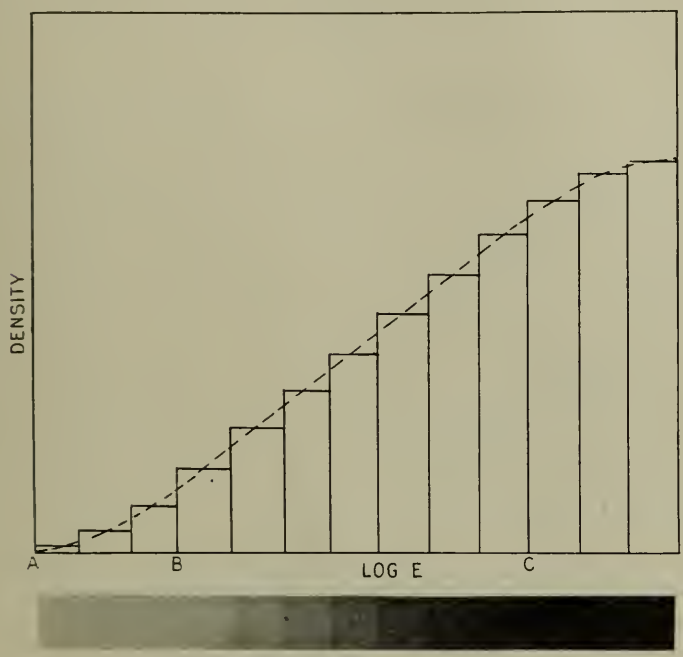
Diagrammatic cross section through ideal negative.

that is, if we cut an imaginary section through the negative so as to show the height of the deposit of silver, it would look as shown in Fig. 2.

If we actually try this experiment upon a plate, however, we find that the densities do not show this equal rise with exposure throughout the entire scale. What we get instead is shown in Fig. 3, and this diagram requires careful study. Starting at *A* and proceeding to *B*, we notice that at the beginning, in the lower exposures, the steps are marked by a gradually *increasing* rise. A negative, the gradations of which fall in this period, will yield prints in which an increasing contrast is shown between tones of uniform increase of brightness; that is to say, the negative will appear what we term "under-exposed." From this period at *B* we pass imperceptibly into the period where the densities show uniform rise for each equal increase of exposure, and here we have our technically perfect negative, that is, one in which

the opacities are exactly proportional to the light intensities of the subject. This is termed the "period of correct exposure," and only through this period of the curve, where the opacities are directly proportional to the exposures and where the densities show an equal increase each time the exposure is doubled, can we get, in the negative, a perfect rendering of the original subject. From the point *C* onwards we have a gradually diminishing in-

FIG. 3.

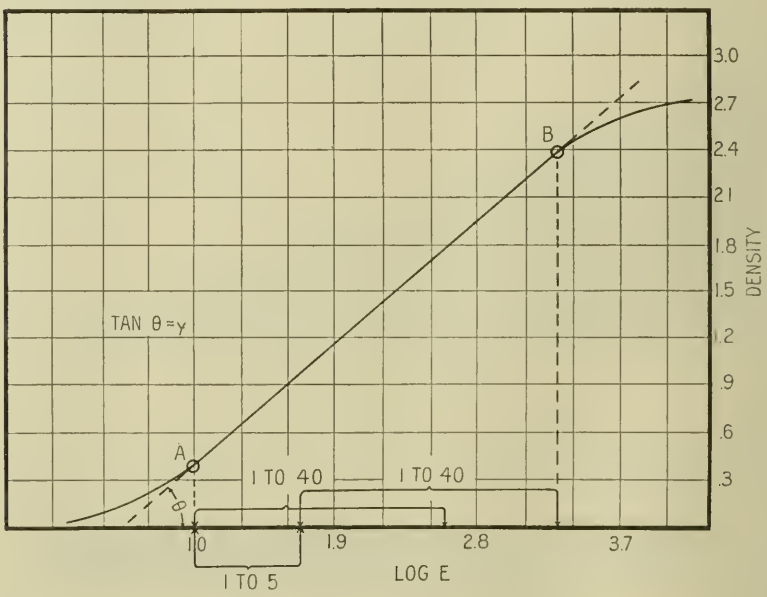


Sensitometric strip with resulting density curves.

crease of density with exposure until finally the increase of density with further exposure becomes imperceptible. This period is the period of over-exposure, in which the opacities of the negative fail to respond to increasing amounts of exposure, and the correctness of rendering is again lost. It will be seen from this curve at once, then, that only through the period of correct exposure, where equal increases of exposure are represented by equal rises in density can the tones of the original subject be correctly reproduced in the negative.

This curve showing the relation between the density and the log exposure was given originally by Hurter and Driffield in their classic paper on photographic theory.* The curve was termed by them the "characteristic curve," and the form in which it is usually plotted is shown in Fig. 4. As has already been stated, throughout the period of correct exposure the curve is represented by a straight line. If this straight line is produced to cut the exposure axis, it will meet it at a point log *i*, where *i* was termed by Hurter and Driffield the "inertia" of the sensitive

FIG. 4.



Characteristic curve showing available latitude.

material, the value being stated in exposure units so that the intercept of the straight line on the exposure axis is measured as the logarithm of the inertia.

The tangent of the angle which the straight line makes with the exposure axis was called by Hurter and Driffield the "development factor" and is signified by γ. During development the inertia point *i* does not change, as is shown in Fig. 5, but the steepness of the straight-line portion of the curve increases

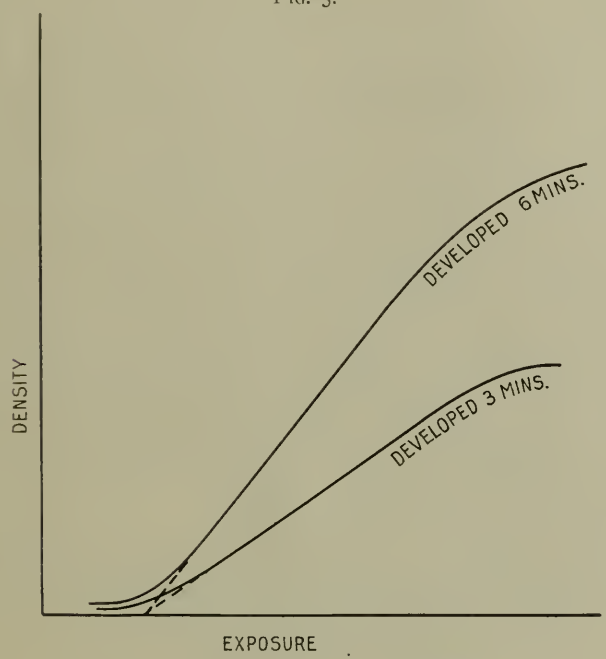
* F. Hurter and V. C. Driffield, *Jour. Soc. Chem. Ind.*, May, 1890.

so that gamma depends upon the time of development. The equation for the straight-line portion of the characteristic curve is therefore

$$D = \gamma (\log E - \log i)$$

A scale of tone values will be proportionately reproduced in a negative in so far, and only in so far, as it falls within the straight-line region of this curve, the length of the straight-line

FIG. 5.



Change of gamma with time of development.

portion being termed the "latitude" of the material. This property varies very much in different negative-making materials, being least in contrasty process plates and greatest in long scale portrait plates. The total range of exposures falling on the straight-line portion of the longest scale plates may be as great as 1 to 200, and a subject having a scale of 1 to 40 may therefore be placed within the straight-line portion of the negative with exposures varying from 1 to 5, this being the effective latitude of exposure available on such a material without any effect being

produced upon the accuracy of the tone rendering. The conditions for correct translation of the tones of the subject into corresponding opacities in the negative are therefore:

1. That the negative material has a long straight-line portion to its curve.

2. That the exposure is such that the scale of intensities of the subject falls entirely within this straight-line portion.

THE EFFECT OF DEVELOPMENT UPON THE SCALE OF THE NEGATIVE.

As is shown in Fig. 5, two negatives developed for different times will give curves similar in shape with their straight-line portions meeting at the same point on the exposure axis, but the slope of the two curves will be different, that developed for the longer time being steeper than that developed for a shorter time. This result was found by Hurter and Driffield, and it follows from it that the ratio of the densities in a photographic negative remains constant throughout development, each density increasing to the same proportional extent. The value of I is therefore a measure of the contrast of a negative, and it is customary to express such contrasts in terms of the numerical value of γ, *i.e.*, of tan θ where θ is the angle made by the straight line with the exposure axis. Thus, with γ equal to unity, the rate of increase of density is proportional to the logarithmic increase of exposure, and the opacities of the negative are exactly proportional to the intensities of the subject photographed.

During development γ increases from O to a limiting value $\gamma\infty$. The rise of γ is exponential, the velocity of development being represented approximately by the equation for a reaction of the first order, which may be written

$$K = \frac{1}{t} \log \frac{\gamma\infty}{\gamma\infty - \gamma}$$

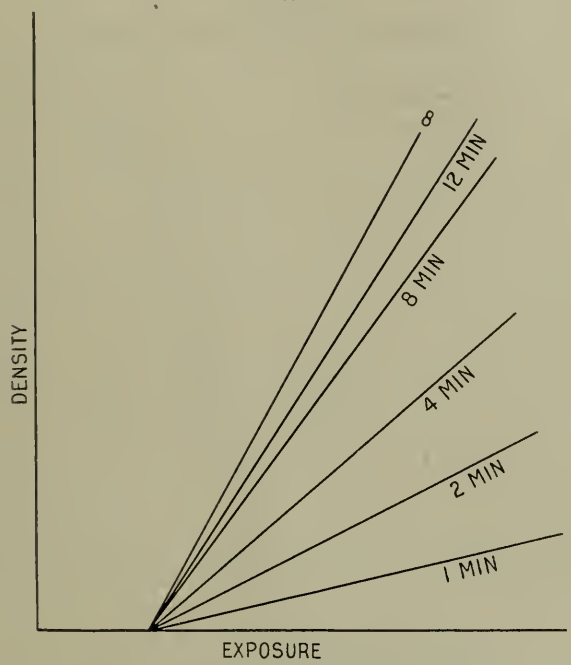
or, in the exponential form

$$\gamma = \gamma\infty (1 - e^{-kt}$$

Figs. 6 and 7 show the calculated γ's for a material having a $\gamma\infty$ of 2 0 and a value of k of .100. The value of $\gamma\infty$ depends upon the photographic material itself. High speed portrait plates have low values since no portrait requires development to a γ exceeding unity. Plates used for landscape work and commercial photography have higher values and will give greater contrast on develop-

ment. They develop more quickly and easily and give contrasts exceeding the maximum to which the fast materials can be pushed, while the greatest contrast of all is obtained with the special, low-speed emulsions made for process work, where every effort is made to get the greatest possible contrast in order to obtain clear lines on a completely opaque field. The maximum contrast given by process plates is frequently as high as 4, which

FIG. 6.



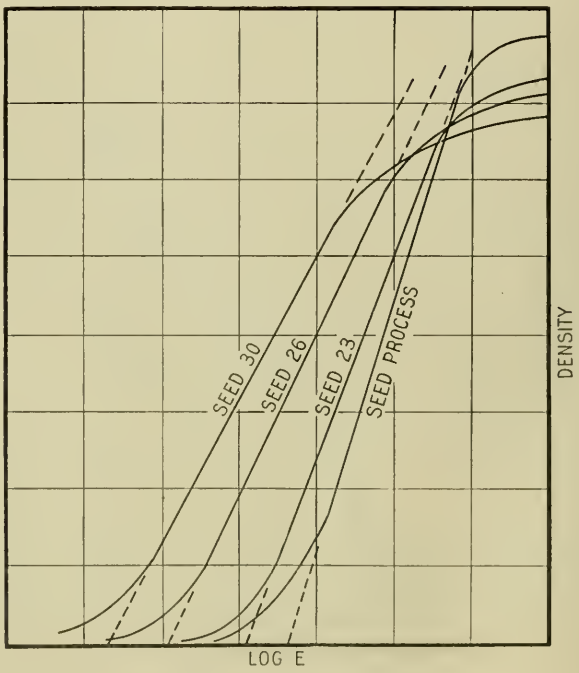
Variation of gamma with time of development.

means that, if we have two tones in the original subject, one of which is twice as bright as the other, the part representing the higher tone in the negative will transmit only one-eighth of the light of that corresponding to the lower tone. Fig. 7 shows the curves of four different plates of the same manufacture, each having been developed to the maximum contrast possible. The notable differences in sentitiveness, scale, and contrast are very well shown in this figure.

The contrast to which a negative should be developed will,

of course, depend upon the contrast of the original subject. Suppose that we have a range of brightness values from 1 to 100 in our subject. If we develop the negative to a contrast of unity, and if the length of the straight line—representing the quality of the material—and the exposure are such that we get exact reproduction of the entire scale of the subject in the negative, we shall have a negative in which the ratio of the highest to the lowest

FIG. 7.

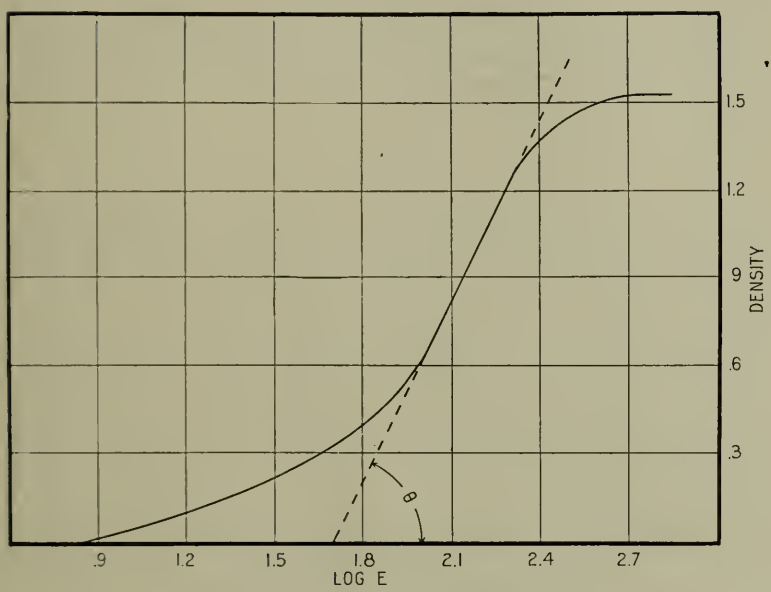


Characteristic curves of typical plates.

transmission is the same as that of the highest to the lowest brightness of the subject; namely, 1 to 100. If this scale of negative densities is too great for printing on the papers which are available, we can reduce the scale by lowering the contrast of the negative; that is, by developing the negative for less time, which will reduce each density in the same proportion. On the other hand, in the case of "flat" subjects (low contrast) we can lengthen the time of development, thus increasing the resulting

contrast in the negative. Provided that the contrast of the subject is not too great for the latitude of the negative material and that the exposure is such that the tone scale of the subject falls on the straight-line portion of the curve, development to a gamma of unity will make the scale of intensities (*i.e.,* transmission values) of the negative the exact inverse of the scale of intensities (brightness values) of the subject.

FIG. 8.



Characteristic curve of developing-out paper.

PRINTING PAPER.

The characteristic curve of a printing paper can be determined in exactly the same way as that of a negative-making material except that instead of measuring the light transmitted by the various densities, the light reflected from the various portions of the print must be measured. We thus get a series of reflection densities from the paper corresponding to the transmission densities of the negative. The characteristic curve of a paper will be of the form shown in Fig. 8.

It will be seen that the following constants will be of importance in specifying the properties of photographic paper. The

maximum black; that is, the reflecting power of the darkest (minimum reflecting power) deposit that can be obtained on the paper with full development and exposure. Such a deposit may reflect from 2 per cent. to 10 per cent. of the incident light, the average value of the maximum black for photographic papers being about 5 per cent., corresponding to a reflection density of 1.30. Matte papers will give a reading from 1.10 up to 1.35; semi-matte papers from 1.35 to 1.50; and glossy papers from 1.50 to 1.8. The total scale of the paper may be defined as the range of light intensities, expressed either in log exposure or exposure units, which can be reproduced by the paper as perceptibly different densities. This must be determined by some assumption of the value

$$\frac{dD}{d \log E}$$

which limits the useful gradient of the curve. In practice, the total scale of the paper is taken as the distance measured on the exposure axis between the points on the curve at which the value of $\frac{dD}{d \log E}$ is .2. The total scale of a paper will consist of three distinct parts—the under-exposed portion, the straight-line portion, and the over-exposed portion of the curve. The slope of the straight-line portion can be represented by γ, though γ does not change with development in the case of gaslight printing papers in the same way as in the case of negative materials. It is quite possible for two papers to have the same scale but different values of γ. This is shown in Fig. 9, where the paper marked *B* has a much steeper straight-line portion than the one marked *A*, but both have the same total scale value.

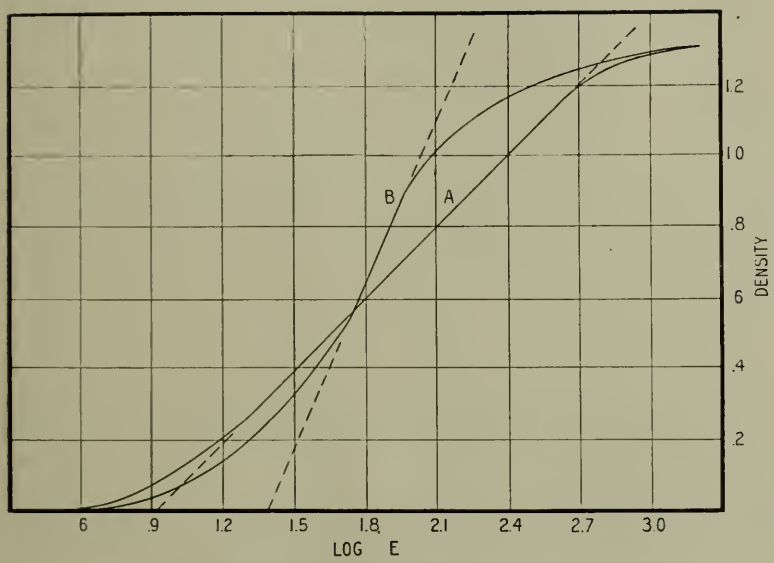
In choosing a paper for printing from a given negative, it is obvious that if all different densities in the negative are to be rendered as different densities in the print, the exposure scale of the paper must be at least as great as the difference between the maximum density and the minimum density of the negative. If the maximum density of a negative is 1.7 and the minimum density is .4, the logarithmic scale of the paper must be 1.3, or the scale in exposure units must be 20.

In order that papers may be suitable for various types of negatives, they are made with different scales. Thus, papers for amateur negatives, which tend to flatness, are made with

fairly short scales ranging from 20 exposure units down to 5 in the most contrasty paper made, this being suitable only for negatives with a maximum density difference of .7. On the other hand, the scales of papers intended for portraiture, where the negatives are of good quality and have a long scale of densities, are of the order of 40 to 60.

Exact reproduction of the tone values of the negative and consequently of the subject upon the printing paper can be accom-

FIG. 9.



Illustrating equality in total scale of different papers.

plished only through the straight-line portion of the characteristic curve of the printing paper. Owing to the narrow range of reflecting powers available in prints, however, it is almost imperative to use the entire density scale of the paper and consequently to sacrifice truth of rendering at both ends of the scale, since the straight-line portion of the curve of the printing paper covers only a small part of the total scale. The ratio of the straight-line portion of the total scale is termed the "rendering power" of a printing paper, and this ratio measures the capacity of a paper to give correct proportional reproduction of a scale of exposures. Thus, a paper that is perfect in rendering power would throughout

its total scale produce densities proportional to the exposure. It is not necessary for correct, proportional rendering for the slope of the straight-line portion to be unity, for as long as the line is straight, the rendering is proportional, but a change in the value of γ will produce a change in the proportionality factor, that is, in the contrast. It is obviously impossible with photographic papers to obtain an exact reproduction of a scale of tones extending over a very wide range such as exists in practical work. As has been shown, it is possible to reproduce exactly in the negative a range of brightness of from 1 to 40 and still retain a latitude of exposure of 1 to 5, but the maximum range of the reflecting power in the straight-line portion of the curve of any printing paper is very limited and in order to reproduce a range of tones greater than this maximum it is necessary either to compress the scale by developing the negative to a lower gamma, thus changing the proportionality factor of reproduction, or to utilize portions of the characteristic curve lying outside the latitude of the paper and thus depart from correct rendering.

EASTMAN KODAK COMPANY,
ROCHESTER, N. Y.
December, 1919.

Pollution of Deep Wells at Lansing, Michigan, is described by the State Sanitary Engineer, MAJOR EDWARD D. RICH, in the *American Journal of Public Health,* 1920, x, 147–151. The water supply of Lansing is derived from 32 wells which vary in depth from 350 to 400 feet. The water became contaminated with polluted ground water; an epidemic of dysentery and typhoid resulted; and chlorination became necessary to provide a safe supply. When such wells are constructed in the best possible manner, three avenues still exist by which dangerous pollution may suddenly occur. The joints and piping may deteriorate. Pumping in excess of the normal capacity of the wells tends to open the texture of sandstones and to enlarge any fissures which may be present; entrance of surface water seepage is thereby facilitated. Another well may be sunk to the same water-bearing stratum in the search for water, oil, or salt, then be abandoned without plugging sufficiently tight to exclude surface water. The conclusion is drawn that deep wells situated in the midst of urban development require the same watchful care that would be given to a shallow well supply or to a surface supply known to be subject to periodical contamination. This care is a requisite even though the depth and mode of construction of the wells would seem to render it unnecessary. J. S. H.

FLOTATION.*

BY

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FLOTATION is a process of mechanical concentration of ores. Its significance and its unique position in the metallurgical art can be best understood by considering, first, the state of the art of mechanical concentration prior to its introduction.

The process of getting to manufacturers the metals, copper, zinc, lead, etc., on which their industries are based is a complex one. These metals occur in Nature as minerals, usually in chemical combination with sulphur. Such minerals are called *sulphides*. Sulphides are found in the earth associated with various worthless minerals, quartz and other silicates, limestone, etc., which form the bulk of the rocks we see every day. If this association contains a sufficient amount of the metal to permit economic extraction, the rock is called an *ore*. The first step in getting the metals is mining the ore. As it comes from the ground, however, most ore contains such a large amount of worthless material, called *gangue*, that before it can be economically treated by chemical means to extract the metals themselves it must usually be treated by some mechanical means to separate the valuable mineral from the worthless rock. This mechanical treatment is called *concentration*. It divides the ore into two parts, a *concentrate*, much smaller in bulk and higher in metal content than the original ore, and a *tailing*, which contains the bulk of the gangue with but a small portion of the valuable mineral. The concentrate goes to the smelter for chemical treatment, which drives off sulphur and associated impurities and gives more or less pure metal. The tailing goes to waste.

The purpose of concentration is, of course, to cut down the cost of the subsequent chemical treatment. There are three measures of the efficiency of concentration: (1) *Grade of the*

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* Presented at a meeting of the Mining and Metallurgical Section held Thursday, April 11, 1918.

concentrate, by which is meant the percentage of metal contained in the concentrate; (2) *ratio of concentration,* which is defined as the ratio of the weight of original ore to the weight of concentrate produced from it; and (3) *percentage of recovery,* which is defined as one hundred times the quotient obtained by dividing the weight of metal contained in the concentrate from a given lot of ore by the weight of metal in the lot. When grade of concentrate, ratio of concentration, and recovery are high, concentration is efficient, and *vice versa.*

Concentration comprises two operations: (1) Severing the valuable mineral from the worthless rock with which it occurs associated and (2) subsequently separating the grains of valuable constituent from admixed grains of worthless rock.

Gravity concentration, by means of which the bulk of copper-, lead-, and zinc-bearing minerals have been separated from the worthless part of their ores in the past, consists in subjecting the ground mixture of valuable mineral and gangue to two supplementary processes, *viz.,* sizing and sorting. Either may precede the other. Sizing may be done by screens or by thin films of water flowing over inclined planes. Sorting is done in the mills by various mechanical modifications of the sorting action of streams, ponds, and quicksands. If a mixture of heavy sulphide and light gangue particles of the same size is introduced into an upward current of water of the proper velocity, the lighter part will be floated away and the heavy part will sink to the bottom. Or if a mixture of particles of the same materials with equal settling velocities—*i.e.,* water-sorted—is subjected to sizing, the large grains of light mineral will be separated from the small grains of heavy mineral. The treatment of an ore by these supplementary processes is, in its essentials, *gravity concentration.*

The bugbear of gravity concentration is the saving of the valuable mineral in the *slimes;* that is, in the very finely divided material. On such material it is difficult, by gravity concentration, to make recoveries exceeding 30 to 50 per cent. of the total mineral value present; the concentrate is low-grade and the ratio of concentration is low. That is, the concentration is inefficient and the subsequent smelting very expensive.

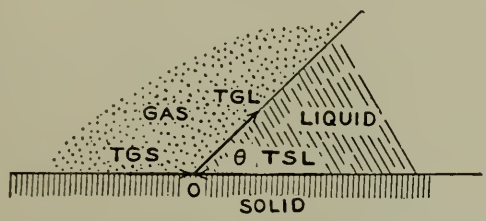
Flotation operates at its best on these slimes, and can make recoveries ranging from 85 to 98 per cent. of the total metallic

content of the ore, the grade of the concentrate being many times better than that of the concentrate made on the same class of material by gravity concentration methods.

Flotation is concentration upside-down. The same sulphide minerals of lead, zinc, and copper which were separated from the worthless rock in gravity concentration by causing them to sink away are, in flotation, caused to float while the particles of gangue sink. Separation is thus effected; this, notwithstanding the fact that the valuable minerals are generally much heavier than the associated gangue.

A simple experiment illustrating flotation is described below. The materials and apparatus necessary are: an agitator, a square

FIG. 1.



Enlarged view of forces at three-phase contact, as in case of floating needle.

jar, water, ore ground to pass a screen with an aperture of 0.15 to 0.20 mm., oil and concentrated sulphuric acid. The agitator is preferably of the type known as a bar- or soda fountain-mixer, having a stirring shaft extending downward from a small vertical motor; but a high-speed egg beater will serve the purpose. For most ores a steam-distilled pine oil or a coal-tar creosote or a mixture of either or both with a petroleum product will serve. Having the materials, mix the ore and water in the proportions one of ore to four of water by weight in such quantity as to fill the jar two-thirds full. Add a few drops of oil and agitate violently for two or three minutes. Allow the mixture to come to rest. If no froth rises, add more oil and repeat the agitation. If the froth contains much gangue, the addition of from 5 to 25 pounds of sulphuric acid per ton of solid will often serve to clean it up. Several trials will usually be necessary before a satisfactory oil mixture is found.

A test run as just described is qualitative only. For quantitative work the Janney laboratory machine is by far the best

yet devised. This works with a charge of slightly more than one pound of ore, discharges froth continually, and circulates the pulp (wet ore) through the machine again and again in order to allow each particle of sulphide many chances to float.

HISTORICAL.

Oil for collecting metals is mentioned by Herodotus in his story of the virgins who collected gold from the mud of a lake by means of feathers daubed with pitch. The process seems, however, either not to have been commercially successful or to have been kept, so far as the mining public was concerned, a secret process, for in 1860 an inventor came forth with the idea of the preferential affinity of oil for metallic minerals as entirely new. The patent literature on the subject from that date to the present is an interesting study, but too involved for presentation in this paper. The first commercial flotation installation in the United States was in 1911. The present importance of the process may be judged by the fact that with such a recent beginning the tonnage treated by this method last year exceeded that treated by gravity concentration.

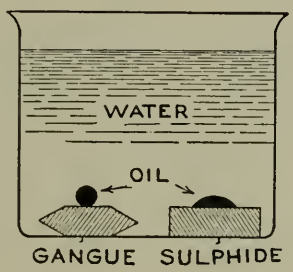
There are at present two distinct types of flotation processes: (1) *Skin flotation;* (2) *froth flotation.* The first is an application of the favorite parlor trick of floating a "greased needle" (see Figs. 3 and 4). It depends upon the greater reluctance of water to wet minerals of metallic lustre than those of vitreous or earthy lustre in the presence of air. It is a manifestation of the force residing in the surfaces of contact between any two dissimilar phases in Nature. This force is called *surface tension.* It causes the substance at the boundary between the phases to act somewhat as a stretched skin would act to resist rupture. Just as the steel needle floats when it is carefully laid on the surface of plain water and as a similar needle of glass will not float, so if a mixture of minerals of metallic and non-metallic lustre is gently brought onto the surface of still water, the mineral with metallic lustre will float, the other will sink and a separation thus be effected. The process is not, however, efficient nor of wide application.

The two essentials to successful froth flotation are (1) the selection of the valuable mineral from the gangue and (2) the formation of a froth of sufficient stability to allow for its separa-

tion from the bulk of the pulp. What actually happens in the selection of the valuable metallic mineral from the gangue is illustrated in Fig. 2. In this figure are shown drops of oil clinging to particles of sulphide and gangue immersed in a body of water. The drawing is a diagrammatic representation of a simple experiment. The particles of sulphide and gangue, after immersion in the water, are touched with a capillary pipette containing oil and some of the oil is forced out. It quickly spreads on the surface of the sulphide and draws together in spherical shape at the surface of the gangue particle.

The explanation of this phenomenon involves (1) the conception of potential energy at all contacts of dissimilar physical phases, and (2) the law of least potential energy.

FIG. 2.



The first conception is stated as follows: At the contact of any two unlike, distinct physical phases there exists a certain definite amount of energy per unit of area. This conception has been proved for any number of contacts. Its effect is illustrated qualitatively by the floating needle previously mentioned.

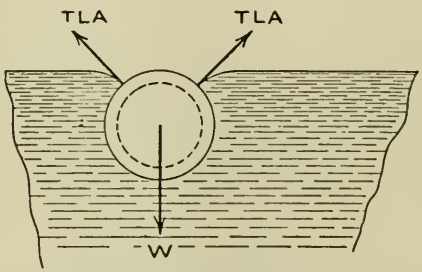
The law of least potential energy states that every physical system tends toward a condition in which the potential energy of the system is least. Familiar examples of the manifestations of this law are the tendency of water at the top of a hill to flow to the bottom and reduce its capacity to do work—in other words, reduce its potential energy; and the tendency of a stretched elastic or spring to decrease its own length—in other words, reduce its ability to do work or come to a condition of least potential energy.

Bearing these two conceptions in mind, it will be seen that the spreading of oil on the surface of the sulphide, thereby displacing water from that surface, is a manifestation of the prin-

ciple of least potential energy. Further, we may conclude that the energy of the oil-sulphide interface is less than that of the water-sulphide interface, since such a condition only would allow for the spreading of the oil. Similar reasoning leads us to the conclusion that the energy of the water-gangue contact is less than that of the oil-gangue contact.

If, now, we consider an oil-water boundary as the fixed part of a system composed of oil, water, sulphide and gangue (Fig. 8) and the sulphide and gangue particles the movable parts of the system, and if we consider the solid particles presented at this boundary, the sulphide will tend to pass into the oil, because such

FIG. 3.



Floating steel cylinder ("greased needle"). Tangent to liquid surface at gas-liquid-solid contact makes large angle with horizontal and cylinder floats.

a position will represent for it the position of least potential energy, while the gangue will tend to pass into the water for the same reason. If, then, we can form a system of oil, water, gangue, and sulphide in which all the sulphide and gangue particles are presented at the oil-water boundary for sorting, we shall have a means of selecting the gangue from the sulphide. And if, after such selection has taken place, the selecting surfaces with their selected sulphide can be separated from the body of the pulp containing the worthless gangue, we shall have completed a process of concentration. This is done by introducing into the sulphide-gangue-oil-water system a large number of air bubbles. Whenever one of these bubbles, in its movement through the pulp, comes into contact with an oil globule, the oil will spread over the air-liquid interface under the action of the law of least potential energy, for the reason that the energy of an oil-air interface is less than that of an air-water interface, and an oil-air contact

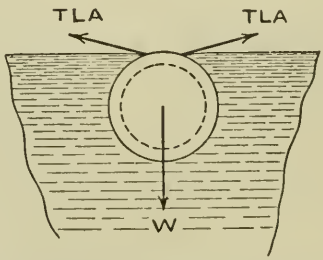
represents, therefore, a state of less potential energy than an air-water contact. At the surface of each such air bubble in the pulp there will be an oil-water interface for sorting sulphide from gangue (Fig. 7), and the sulphide will move into the oil away from the body of the pulp. As the bubble moves to the surface of the pulp through the influence of gravity the oil with its load of sulphide will move with it. At the surface the mass of sulphide-loaded bubbles will persist to form a froth.

FROTH FORMATION.

The mechanics of froth formation can best be explained by the following series of experiments. Persistent bubbles, hence a froth, cannot be formed in water alone. This is due to the fact that a pure-water film cannot, except by the merest accident, come to a state of equilibrium between the force seeking to distend the bubble and the surface tension. Neither can a froth be formed with pure oil. A mixture of oil and water can be made to froth slightly on account of the fact that a film forms at the interface between the oil and water which has a sufficiently high viscosity to overcome the tension of the oil-air and oil-water interfaces. This film is illustrated in the photograph, Fig. 5, the phenomena of which are diagrammatically represented in Fig. 6 on the same plate. The photograph represents a square glass cell, having at the bottom a layer of water colored with red ink, and above a layer of kerosene. The red ink is added in order to make the phenomena more easily visible. Air is introduced through a tube into the water layer, the bubbles rise to the interface between the water and oil, and here immediately the viscosity of the interfacial film is apparent in the way in which the film is drawn up by the air bubble, as illustrated at *H*, Fig. 6. Eventually the bubble breaks free and rises through the oil layer with a coating of colored water, as illustrated at *M*, Fig. 6. This bubble rises to the surface and assumes momentarily the shape shown at *C*, Fig. 6. Shortly this water sheath falls away and drops back through the water layer in a bowl-shaped mass, as illustrated at *P*, Fig. 6. At the same time there may be seen dispersed through the oil the tadpole-shaped water drops illustrated at *T*, Fig. 6. The water drops *P* and *T* are conclusive evidence of the high viscosity of the interfacial film between oil and water. It is apparent, of course, that, since the energy of the interface between the oil and

the water is a constant, the drop will tend to assume the condition of least potential energy by reducing its surface to the minimum, and, the sphere being the body of least surface for a given volume, the drop will tend to assume a spherical shape. But, since the drops do not assume the spherical shape under the influence of surface tension, it must be further apparent that their tendency to do so is opposed by some other force. This force is the viscosity of the interfacial film. Such a viscous film aids a bubble with an oil-water film to persist and is one of the causes of the temporary persistence exhibited by bubbles formed from a mixture of oil and water. The other cause of such persistence is the

FIG. 4.



Sinking glass cylinder. Tangent to liquid surface at gas-liquid-solid contact makes small angle with horizontal and cylinder sinks.

variable surface tension of the oil-water film. Such a film, when subjected to a stress greater than its surface tension can resist, stretches, and in so doing increases its area. The concentration of the substance of lower surface tension (the oil) per unit of area now becomes less and the resultant tension of the film increases. If the increase is sufficient to balance the external stress, equilibrium is attained and the film persists.

In the flotation process this variability in surface tension is but a small factor in the stability of the film. The great factor is increase in viscosity, due, however, not so much to the viscous films at the oil-water interfaces as to the introduction into the bubble films of finely divided solid matter. The stabilizing effect of finely divided solid matter on liquid films is familiar to every one in the action of rain drops on a dusty road. Such drops will become coated with dust, and, if the surface of the road is hard and sloping, these dust-covered drops will roll for a considerable

distance along the surface, preserving their spherical shape. The phenomenon can be illustrated in the laboratory by floating a match on the surface of a beaker of water; placing a chip at the side of the beaker, then causing the match to revolve slowly, when it will be seen that the match can be turned around the vertical axis of the beaker without any corresponding motion of the chip. If, now, the surface of the beaker is dusted over with finely divided solid matter, a film forms, and when the match is again caused to rotate the film and the chip—in fact, the whole surface of the contents of the beaker—move with the match. This, of course, can be due only to the increase in viscosity of the surface film. The surface of an oil-coated air bubble in a

FIG. 5.

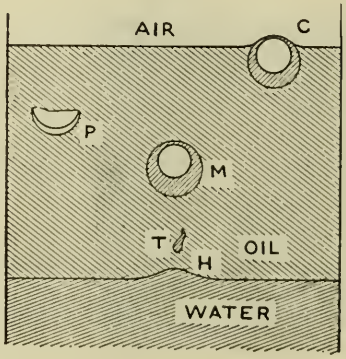
pulp, after it has picked up its load of solid, is similar to the water surface just described.

No physical principle other than the law of chance need be appealed to in order to explain the meeting of oil globules with air bubbles, or the meeting of sulphide particles with oiled bubbles. There are about three hundred million solid particles of the size that we are considering formed from every cubic inch of solid matter. In a flotation pulp (mixture of ore and water as sent to the machine) there are at least sixty million particles per cubic inch. The opalescence caused by agitating together the water and oil before addition of the ore will show that the oil is as thoroughly dispersed. Given, then, at least sixty million particles of solid and sixty million oil particles per cubic inch, and introduce air bubbles, in the same or greater number, and failure of the

air bubbles, oil globules, and sulphide particles to collide will take some phenomenal steering. It is obviously unnecessary to appeal to any mysterious forces to bring about a meeting.

To summarize, then: We bring to the machine a freely flowing mixture of ore and water, the pulp; we add oil; agitate to disperse the oil through the pulp; agitate further to introduce air in finely divided form, and agitate yet further to cause the air bubbles to come into contact with oil and sulphide particles. The oil spreads over the surface of the air bubbles because by so doing it lowers the potential energy of the oil-air-water system. A sulphide particle subsequently meeting the oiled air-bubble passes into the oil film because in this position it is in the state of

FIG. 6.



least potential energy, and the gangue particle, meeting the oiled air bubble, passes back again into the water because this position for it represents the state of least potential energy. The sulphide-coated, oiled air bubble rises through the pulp, due to its smaller specific weight, and upon reaching the surface of the pulp persists, on account of the high viscosity of the solid-loaded film surrounding it. The froth formed by the persistent bubbles is scraped off and a separation is thus made between the sulphide and the gangue originally present in the ore.

COMMERCIAL MACHINES.

Commercial froth flotation machines are of three types: (1) the so-called mechanical agitation machine, which depends solely upon mechanical agitation for the dispersion of the oil in the pulp

and the introduction of air; (2) the pneumatic froth machine, in which the air is introduced through a porous bottom, the only agitation to which the pulp is subjected being the gentle agitation due to the rising of the mass of air bubbles through the pulp; and (3) the so-called mechanical-air machine, which is a combination of the other two, using mechanical agitation for dispersion of the oil through the pulp and for the introduction of part of the air, and having also an arrangement for introducing air through a porous bottom under the mass of pulp which has been previously subjected to mechanical agitation.

The mechanical agitation machine consists, in the best form, of an agitating compartment above which is mounted a vertical

FIG. 7.

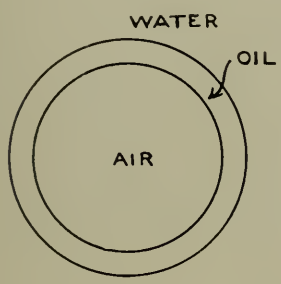
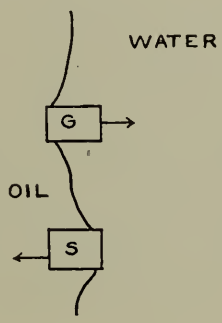


FIG. 8.



motor with an extension shaft reaching down into the box and bearing two cross-shaped beaters. Pulp is introduced into this box through a pipe near the bottom, is agitated by means of the beaters, and discharged over the top underneath a baffle, below the surface of the pulp in the two pointed boxes, or *spitzkasten,* placed one at either side. These *spitzkasten* afford a quiet place in which the pulp comes to rest allowing the bubbles with their load of sulphide to rise to the surface and collect as a froth. The froth is removed mechanically by means of scrapers. The material not in the froth settles to the bottom, part of it passes on into an adjoining *spitzkasten,* and part of it is sucked back through a pipe, into the beater box again. This cycle is repeated a sufficient number of times to insure the saving of a large part of the sulphide mineral. These machines are set up in batteries of from 6 or 7 to 16 or 17 in series.

The pneumatic froth machine is typified by the Callow cell. This consists of a box 18 inches to 2 feet wide, 6 feet to 10 feet long, with a sloping porous bottom ranging in depth from 8 or 10 inches at the head end to about 4 feet at the discharge end. Pulp is fed into the box at the shallow end, behind a baffle, flows out into the main box, and is there subjected to the action of a rising column of bubbles formed from air introduced through the porous bottom. The porous bottom is divided into compartments, each with a separate air supply, the purpose being to so regulate the air as to just overcome the hydrostatic pressure at each depth. The froth overflows at the sides of the box into launders and is carried away as concentrate, while the tailing is discharged through a valve at the lower end of the machine.

The best-known mechanical-air machine differs from the mechanical machine first described only in that the *spitzkasten* are fitted with porous bottoms through which air is introduced into the already partly aërated pulp discharged from the agitating compartments. This air lightens the froth materially, makes it much more tender, yet by greatly increasing the number of bubbles rising through the pulp lessens the number of sulphide particles which drop to the bottom of the *spitzkasten* and pass off into the tailing. The use of air also does away with the necessity for mechanical froth removers.

FLOW SHEETS.

The way in which mills using flotation are arranged depends upon the way in which the sulphide mineral occurs in the ore. There are perhaps three typical mill installations in which flotation is used. The first of these applies to an ore in which the sulphide mineral occurs in relatively coarse aggregates. Such an ore is treated by crushing to the point where a portion of the mineral is severed from the gangue, then commences a scheme of sizing and classification, the various coarser sizes being treated by water concentration to remove concentrate, making a middling product which is sent to regrinding machines. The finest product of the preliminary grinding and the products of the regrinding machines are combined and sent to the flotation plant. This is a typical mill scheme where flotation has been introduced as a slime-treatment accessory to older processes, and is the most economical scheme where the mineral is sufficiently coarse so that

a considerable portion of it can be removed with good recoveries by water concentration.

The second type of mill is that in which the sulphide mineral occurs disseminated as minute grains throughout the ore. In the treatment of such an ore it is necessary, in order to sever the sulphide grains from the gangue, to grind very fine in the first instance; in other words, to slime the whole pulp. When such a process is carried out the whole mill feed is sent to the flotation plant and little or no gravity concentration is attempted.

The third type of flow sheet applies to ores in which the sulphide mineral is not quite so finely disseminated as in the last instance, but where the amount of mineral coarsely disseminated is not large. In such a case it has been deemed economical to grind all the pulp down to such size that the flotation machines can move it without banking, and yet not to such size that all the sulphide mineral can be raised in the froth. The pulp thus ground is passed first to the flotation machines, which take out the fine sulphide particles. The tailing from these machines is then passed to gravity concentrating devices, where the coarser sulphide is taken out, and the reject from these machines is discharged from the mill as finished tailing.

The actual flotation plant is arranged according to two general schemes: (1) The so-called roughing-cleaning scheme, and (2) the so-called concentrate-middling scheme. In the first of these the concentrate from the first cells is taken off relatively dirty and sent to another set of machines called cleaners, which make a high-grade concentrate and discharge a relatively rich pulp. This latter constitutes a middling which is ordinarily joined with the froth from the later cells of the rougher machine and the whole sent back to the head of the rougher machine for retreatment. The pulp discharged from the rougher machine constitutes tailing. In the concentrate-middling scheme the first cells are run to give a clean concentrate. The later cells are run to take over dirty froth and insure the discharge of a clean, impoverished tailing. The dirty froth is returned as middling to the head of the machine.

Applicability.

Flotation can be applied to any ore in which the mineral containing the valuable metal has a metallic lustre and the gangue

has a vitreous or earthy lustre. If the gangue also has metallic lustre or two minerals, such as the sulphides of lead and zinc occur together, the problem of differential flotation arises. This problem cannot be said to be yet completely solved. When the valuable metal is combined with oxygen alone or with oxygen and carbon or silicon, giving oxides, carbonates, or silicates, the so-called oxidized ores, another unsolved problem arises, so far as flotation is concerned, although some successful experiments on such ores have been reported. We may expect to see both of these problems solved in the not-too-distant future.

Some Large-Scale Experiments Imitating the Craters of the Moon. HERBERT E. IVES. (*Astrophys. Jour.*, Nov., 1919.)—On the surface of the moon are features consisting of circular rings of the material of this body, elevated above its surface and surrounding level floors higher than the surrounding lunar surface. Small peaks often rise from these floors. Volcanic action and the impact of meteorites have both been invoked to explain the presence of these craters.

At Langley Field, Virginia, during the war, craters were made by the explosion of bombs dropped from airplanes. Photographs of these taken from airplanes very closely resemble photographs of the lunar craters. The central surrounding wall, the central peak and radiating streaks all are there. The similarity extends even to overlapping craters. Could explosions have caused the lunar craters? To the earth's atmosphere come meteors with velocities ranging from 16 to 64 kilometres per sec. These sometimes become incandescent and burst with loud reports. Owing to the protection afforded by the envelope of air they rarely pit the surface of the earth. The moon, however, has no atmosphere. A meteor, travelling with the lowest speed given above and with an assumed specific heat of .2, would be raised to a temperature of 15,000°C. upon colliding with the surface of the moon, even if nine-tenths of the heat developed were given up to the surroundings. This high temperature would turn any substance into a gas at once and would be the equivalent of an explosion. The crater is thus not the result of the direct impact of the meteor upon the lunar surface but of the consequent development of gas. The angle of incidence of the meteors is of small moment. Though they bombarded the moon from different directions the craters formed did not register those directions since they were thrown up by the outrush of gas.

G. F. S.

ON THE MODE OF FORMATION OF DUST FIGURES ON WALLS AND CEILINGS.*

BY

C. B. BAZZONI, A.M., Ph.D.

THE dust figures which occur on the walls and ceilings of rooms frequently outlining the laths and other underlying structures have been commented upon at different times in scientific periodicals.[1] The figures have been attributed by some to deposits of moisture, and by others to electrostatic or thermal effects.

These figures are of two types. Those of the first type are, in the opinion of the writer, to be referred to local temperature differences on the wall surfaces which cause corresponding irregularities in the moisture deposition from the currents of damp air flowing over them. Areas with a temperature below the dew-point of the vapor in the air become covered with a water film which takes up the dust particles from the air by ordinary adhesion. This dust deposit is possibly increased through deposition resulting from the checking in the velocity of the air current due to the greater surface friction over the wet areas. This simple theory suffices to explain all of the dust figures outlining underlying structures ordinarily observed.

The most common dust figure of this type is that showing up the laths and beams under the plaster. The black areas making up these figures are found to be between the laths. These figures are never marked, if at all present, in interior rooms or on the ceilings of lower story rooms where upper stories are heated. They occur fully developed on the ceilings of rooms covered by a cold attic and on the inner sides of exterior walls. The more rapid convection and radiation of heat from the areas not backed by lath or beam produce the necessary local temperature differences for the production of the irregular water films. A striking illustration of this theory is shown where beams contain tie-bolts or large lag screws the heads of which are covered by the plaster. The locations of these iron bolts are indicated in the dust figures

* Communicated by Dr. Joseph S. Hepburn.

[1] T. D. Cope: *Nature*, vol. xciv, p. 562, Jan. 21, 1915.

by intense black deposits of the size of the bolt head. The greater amount of the deposit is due to the more rapid conduction along the iron bar and the consequent lower temperature at the end. All observations, in short, indicate that for the production of well marked figures the outer side of the wall must be at a lower temperature than the inner and that the rate of heat loss must be greater from some portions of the area than from others.

Figures of the second type occur at the edges of mouldings, cornices or other obstructions which are so situated as to impede the flow of the ordinary ventilation air currents. They are also observed across the edges of cracks in the plastering. These dust figures form irregular streamers at the boundaries of the obstacles in the direction of the air currents. These are surface layers having no relation to the underlying structures of the wall. We may assume these deposits to be produced like the others by the adhesion of dust to moist areas, but the deposition of the moisture can no longer be generally ascribed to temperature differences on the surface. The slight increase in pressure around the obstacle due to the current flow seems the only possible cause of the assumed precipitation of moisture in these cases. On the other hand, the entire deposit may be explained as the effect of the decreased velocity and consequent decreased carrying capacity of the air stream in the immediate neighborhood of the obstacle —adhesion between the greasy dust and the wall taking place with no greater amount of water present than that usually found on the walls of heated apartments. No deposits of this type have been examined by the writer, the formation of which cannot be superficially explained on the basis of this simple hypothesis of deposition in areas of decreased velocity—adhesion following from the ordinary stickiness of the wall.

The explanations of the formation of dust figures given above have been subjected to simple experimental tests in this laboratory. An experimental chamber was constructed about 70 cm. by 30 cm. by 20 cm. in size. The roof was formed by a sheet of compo-board surfaced with Alabastine and resurfaced when necessary. At one end of the box was a glass window made to slide up and down so as to cover or uncover a row of ventilating ports. An iron pipe of 3 cm. bore and 60 cm. in length was brought through the floor at the other end of the box. This pipe had a perforated cork at the bottom through which air, chemically dried,

could be sent by means of a motor driven blower. The cork also supported an electric resistance heater wound on a porcelain pipe. Two glass tubes entered the iron pipe laterally. One of these, about half way up, was used to admit steam when desired —the other, three-quarters of the way up, to admit dust. The dust used was dried precipitated lampblack. This powder was contained in a glass receptacle and was blown into the tube axially by means of a second motor driven blower. With this arrangement a sustained current of warmed air could be circulated through the chamber, passing in its path along the ceiling. This air could be dry or moist as desired and could be supplied with any desired content of dust. It was found that where moist, dusty air was desired so as to get rapid and certain results the best effects were produced by inserting a bunsen burner burning with a smoky flame into the bottom end of the iron pipe after removing the cork and heater. It was also found that the heater could in all cases be substituted for by heating the tube on the outside with a bunsen or blowpipe flame.

The following experiments were performed:

(1) A cold spot was produced on the ceiling by placing on the top of the chamber, outside, a can containing running cold water. A hot spot was made beside the cold spot, but several centimeters distant from it, by placing a circular flat plate electrical heater on the outside of the box lid. With moist, smoky air driven by a smoky bunsen flame visible figures were produced on the ceiling in one minute or less. The cold spot was heavily blackened—the hot spot remained notably cleaner than the rest of the ceiling. The figures had sharp, clean edges.

(2) The box was dried overnight with a large vessel of calcium chloride. The hot and cold spots were produced as before. A current of warm dry air was run through the chamber for fifteen minutes without producing any effect on the clean ceiling surface. Next dust was introduced with the air and kept circulating heavily for fifteen minutes. Large quantities of dust settled in the box but no figures appeared on the ceiling. Next steam was introduced with the dust. A dark figure appeared within a few seconds on the cold spot. After fifteen minutes the ceiling was removed for closer examination. Definite sharp figures were found as in the preceding experiment—dark under the cold spot —white under the hot spot. After the dust had settled a fresh

ceiling was substituted and steam was introduced into the chamber with dust free air. After ten minutes the cold spot was clearly indicated by a moist darkening of the surface due to deposited water.

(3) The object of this experiment was to show that water actually deposited in detectable amount on the cold spot and evaporated from the hot spot. The ceiling was painted with blue litmus solution and then treated with HCl vapor to turn the litmus red. The Alabastine has a natural alkaline reaction so that wherever this prepared red surface was touched with water it turned blue. On the other hand, when the surface was thoroughly dried and the HCl driven off the pink color disappeared, leaving a greyish color like neutral litmus. After passing moist, dust free air through the chamber for ffiteen minutes the cold spot was found to be distinctly blue, the main ceiling surface red and the hot spot grey. The effects were sharply defined like the dust figures.

These experiments show that dust figures of the type studied are produced only in the presence of moisture, and that their configuration is the same as that of the moisture deposits formed by the natural condensation on cold areas and evaporation from hot areas. The formation of the figures is not dependent on the temperature differences excepting in so far as these temperature differences determine the moisture distribution on the surface.

Peculiar graduations in density are frequently observed in the figures on walls, apparently due to an irregular placing of the underlying structures bringing the conducting materials nearer the surface at some places than at others and thus producing a temperature variation on the surface. A fourth experiment was made to determine the effect of small differences of temperature on the densities of the figures.

(4) Four vessels were placed in a row crosswise on the lid of the experimental chamber: (*a*) A can with a flat bottom containing salt and ice—temperature 6°C.; (*b*) a glass beaker containing water—temperature 29°; (*c*) a beaker containing water—temperature 25°; (*d*) a can with a flat bottom cooled with running water—temperature 15°. The beakers had concave bottoms so that they touched only at the edges of their bottoms. After exposure to circulating moist, dusty air for fifteen minutes four definite dark figures were formed. Figure (*a*) was distinctly the most dense;

(*b*) could be seen only with difficulty; (*c*) was easily seen, but not dense; (*d*) was not so heavy as (*a*) but much heavier than (*c*). The deposits under the beakers were distinctly annular, being lighter in the centre. It is clear from this experiment that the density of the figure is a function of the temperature of the area and that the figure will exhibit quite accurately the temperature distribution over the area. The greater temperature difference produces the greater deposition because of the more moist condition of the colder area. It was found, however, that for brief and extreme tests a limit was reached when the temperature was sufficiently low and the moisture sufficiently abundant to form a continuous layer of water with drops. This layer naturally served to protect the surface from actual contact with the dust so that the figure became very light after drying in the open air. The temperature on the top surface of the lid during this experiment was 32°. Immediately below the ceiling, inside the box, the temperature was 42°.

(5) It is possible to imagine that some sort of thermal action may go on in the thoroughly dry apparatus which does not become evident because the dust cannot stick to the under surface of the ceiling but falls away and therefore does not produce any figures. To test this point the ceiling surface was turned upward and supported about three centimeters below the top of the box, the roof being a sheet of glass. The hot and cold spots were produced from underneath. It was found that, when the ceiling board had been very thoroughly dried by heat and dried air and no trace of moist air was present, the dust deposit formed was uniform and unfigured, but that in the presence of the slightest trace of moisture such, for example, as could be produced on the surface by blowing off an accumulation of dust with the breath, definite figures of the usual sort began to appear at once. With moist air or with air driven by a smoky bunsen flame, dense and sharp effects were produced in a very few minutes.

These experiments seem sufficiently conclusive as to the mode of formation of dust figures of the first class—those occurring on flat surfaces on which a temperature inequality exists. The figures produced around obstacles were next studied. Three obstacles were fastened in a row across a clean ceiling surface. The first obstacle was a wooden cylinder about three cm. in diameter and one cm. high. The second was a cube of one cm. edge

and the third was a body about four cm. long by eight mm. at its widest part of approved stream line form. Experiments were performed as follows:

(1*a*) It was first established that figures similar to those observed on ceilings could be formed under the conditions of the experiments. Smoky, moist air driven by a smoky bunsen burner was passed through the chamber. Figures of the characteristic forms began to appear around the obstacles within one minute and were well marked after five minutes.

(2*a*) It was next shown that the figures do not form around dry obstacles on a horizontal ceiling in a current of dry, dusty air. Dry dust filled air was passed over a clean ceiling with obstacles for fifteen minutes. At the end of this time there was absolutely no effect visible in the way of figures.

Figures produced by the methods of (1*a*) seemed, on examination, to suggest strongly that the dust was deposited in areas of positive pressure and cleared away from areas of negative pressure. This was particularly the case around the stream line obstacle. The pressure changes to be expected around cylindrical and stream line obstacles in an air current of the velocity here used were calculated and were found to correspond in power to precipitate moisture to temperature changes not exceeding ½° C. These pressures seemed entirely inadequate to produce effects of the intensity actually obtained. Furthermore, the excess moisture deposition due to positive pressures around the cylinder should lie within a cone opening toward the air current of 70° apex angle while the dust deposition seemed uniform over 180° in the observed figures.

(3*a*) An attempt was next made to find out whether or not any moisture was deposited around the obstacles. A clean ceiling with obstacles was put in place and dust free air containing an excess of steam was passed over it for fifteen minutes. No moist areas appeared. Any considerable amount of moisture would have turned the Alabastine dark. The ceiling was then painted with blue litmus and the blue turned red with HCl vapor as in the first series of experiments. Continued exposure of this surface to currents of moist air failed to produce any figures around the obstacles. On increasing the steam content of the air the entire surface turned blue uniformly with no evidence of extra moisture near the obstacles. These tests served to prove what the calcula-

tions indicated—that no quantity of moisture detectable by the means employed was thrown down around the obstacles.

These results suggested that the figures obtained in (1*a*) were merely shadow effects due to the interference of the obstacles with the air flow velocity. The carrying capacity of a stream is usually assumed to vary with the cube or some higher power of the velocity whence any slight checking of an air stream will deposit dust from it although the associated pressure change may not be great enough to deposit any moisture. If this is the case the figures will form in dry air as well as in moist. Under the conditions of (2*a*) the dust deposited could not be observed, since it settled downward, neither the ceiling nor the dust being sticky.

(4*a*) To test this last assumption, the obstacles were set on the upper surface of a whitened compo-board supported three centimeters below the top of the box, inside, in such a way as to leave openings communicating downwards at either end. The lid of the box was a sheet of glass. Dry, dusty air was passed over the surface bearing the obstacles. Distinct figures of the usual form showed after a few seconds and could be made of any desired intensity by prolonging the flow. These were obviously deposition figures of dry dust due to checking the air current. They were nonadherent and could be blown completely away with a single breath. This experiment showed that the deposits formed, as was anticipated, in the absence of moisture, and explained why no deposit was observed in (2*a*). To get an obstacle figure on a ceiling from dusty air it is necessary to render the ceiling sticky. Water vapor will produce the necessary stickiness.

(5*a*) The internal plate was removed and the obstacles placed on the lower surface of the ceiling as before. Dry, dusty air was admitted with steam. After fifteen minutes the ceiling was found to be covered with a generally distributed adherent deposit with weak though definite figures around the obstacles—dark in front and light behind. These figures were clearly present, were of the same kind as those that occur on ordinary ceilings and were permanent in that they could not be blown off. More marked figures can be produced in the same length of time with a smoky bunsen flame as in (1*a*) apparently because the bunsen smoke is itself more sticky and finely divided than the dried lamp black introduced by the methods here used.

These ten experiments seem to show definitely how and why wall figures of the two types treated are produced. The facts proved are in accordance with what one would expect on the basis of ordinary physical common sense. On account, however, of the methods used in this work it is not claimed that other factors than those affecting the distribution of moisture films as influenced by temperature may not contribute in a minor way to the formation of figures of the first kind. It is merely contended that under all ordinary conditions the temperature-moisture distribution is the factor of predominating importance being necessary and sufficient to produce all of the observed effects.

SUMMARY.

The dust figures commonly observed on walls and ceilings are grouped into two classes. Certain experiments are described showing that those of the first class are due to irregular moisture deposition on the surface caused by a corresponding irregular temperature distribution, and that those of the second class are due to deposition around obstacles caused by decreased carrying capacity of the air stream with decreased velocity.

RANDAL MORGAN LABORATORY,
UNIVERSITY OF PENNSYLVANIA,
November, 1918.

Bacteriology in Food Control.—EDWIN O. JORDAN, of the University of Chicago, concludes a paper on the "Uses, Possibilities and Limitations of Bacteriology in Food Control" (*American Journal of Public Health,* 1920, X, 142–144), with a statement of the future outlook for the application of bacteriology in food control. "Increasing emphasis will be laid on bacterial methods as an aid to the interpretation of the sanitary inspection of foodstuffs and as a guide to satisfactory sanitary procedure. Continued laboratory investigation of the two best-known instances of so-called 'food poisoning' traceable to primary bacterial food contamination, botulism and paratyphoid meat poisoning, seems urgently called for since both are intimately connected with the vital problems of food conservation. Finally the nature and sanitary significance of the products generated by bacteria, particularly the so-called saphrophytic bacteria, in foodstuffs affords a practically untouched field for investigation."

J. S. H.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

A NEW FORM OF VIBRATION GALVANOMETER.[1]

By P. G. Agnew.

[ABSTRACT.]

VIBRATION galvanometers are very useful in a. c. null measurements, but have not been much used in industrial laboratories on account of their being sensitive to external vibrations and requiring delicate adjustments. The present instrument, which has a sensitivity higher than other forms of the moving-iron type, but less than that of the most sensitive forms of the moving-coil type, has the advantages of sturdiness, quick responsiveness and freedom from the effects of external vibration. It consists essentially of a fine steel wire mounted on one pole of a permanent magnet and so arranged that the free end of the wire may vibrate between the poles of an electromagnet through which flows the current to be detected. The motion of the wire is observed with a microscope.

The "resonance range" is about one per cent.; that is, if the frequency of the current is 1 per cent. above or below the frequency of resonance, the amplitude of vibration will be half as great as at resonance. The sensitivity is such that with a 1-ohm winding an e.m.f. of 3 microvolts may be detected, and with a 270-ohm winding a current of 0.05 microampere can readily be detected.

VAPOR PRESSURE OF AMMONIA.[2]

By C. S. Cragoe, C. H. Meyers, and C. S. Taylor.

[ABSTRACT.]

THE previous measurements of the vapor pressure of ammonia are briefly reviewed and tabulated. A detailed description is given of the apparatus and method employed in the present measurements throughout the temperature interval −78° to +70° C. Seven samples of thoroughly purified ammonia were used. Special tests showed less than 1 part in 100,000 by volume of

* Communicated by the Director.

[1] Technologic Paper No. 370.

[2] Scientific Paper No. 369.

non-condensing gases and less than 0.01 per cent. by weight of other impurities. The methods of purification and filling manometers are briefly described. The phenomenon of hysteresis was observed near the normal boiling point of ammonia with a commercial sample containing a small amount of air, which indicated the necessity of very complete removal of dissolved gases for any accurate measurements of vapor pressure by the static method. Lags in coming to equilibrium were encountered and studied in order to determine the most advantageous procedure in establishing equilibrium. The normal boiling point of ammonia was determined by the static and also the dynamic method, the mean of the results by the two methods being −33.35° C. Two empirical equations were found to represent closely the results in the temperature range covered experimentally and also the latest determination of the critical data for ammonia. The results of 122 measurements in the interval −78° to +25° C. made with direct observations of mercury columns agree with the empirical equations within 1 mm. of mercury. The results of 28 measurements in the interval +15° to +70° C. made with an accurately calibrated piston gauge agree with the empirical equations within about 3 mm. of mercury. As a final result the vapor pressure of ammonia is expressed in the range −80° to +70° C. by either of the following equations:

$$\log p = 30.256818 - \frac{1914.9569}{\theta} - 8.4598324 \log \theta + 2.39309 \times 10^{-3}\,\theta + 2.955214 \times 10^{-6}\,\theta^2$$

$$\log p = 12.465400 - \frac{1648.6068}{\theta} - 0.01638646\,\theta + 2.403267 \times 10^{-5}\,\theta^2 - 1.168708 \times 10^{-8}\,\theta^3$$

where p is expressed in mm. of mercury and θ in degrees absolute ($°abs = °C + 273.1$).

IONIZATION AND RESONANCE POTENTIAL FOR ELECTRONS IN VAPORS OF LEAD AND CALCIUM.[a]

By F. L. Mohler, Paul D. Foote, and H. M. Stinson.

[ABSTRACT.]

MEASUREMENTS of electron currents in three electrode vacuum tubes of the type previously described have been made in vapors of lead and calcium.

[a] Scientific Paper No. 368.

The lead and calcium were boiled in porcelain tubes at temperatures of about 1000° and 900°, respectively. Current voltage curves in lead showed a resonance potential of 1.26 volts and an ionization potential of 7.93 volts. Applying the quantum relation $Ve = h\nu$ we find that 1.26 volts corresponds within experimental error to the frequency of a strong infra-red spectrum line at $\lambda = 10{,}291$ Å giving a theoretical value of the resonance potential 1.198 volts.

In calcium two resonance potentials were found at 1.90 volts and at 2.85 volts of which the first is the most prominent. Ionization occurred at 6.01 volts. The ionization potential corresponds to the limit of the principal series $1.5\ S$, $\lambda = 2027$ Å giving as the theoretical value $V = 6.081$ volts. The first resonance is determined by the line $1.5\ S - 2p_2 = 6572.78$ Å, $V = 1.877$ volts. The second resonance corresponds to the line $1.5\ S - 2\ P$, $\lambda = 4228.73$ Å, $V = 2918$ volts.

The spectral relations of the first resonance potential and ionization potential are analogous to the relation found with other metals in this group. Work of other observers shows that both the lines $1.5\ S - 2\ P$ and $1.5\ S - 2\ p_2$ appear below the ionization potential in most metals of this group.

RECOMMENDED SPECIFICATIONS FOR ZINC OXIDE, DRY AND PASTE.[4]

[ABSTRACT.]

PREPARED and recommended by the U. S. Interdepartmental Committee on Paint Specification Standardization, January 12, 1920. This committee was appointed at the suggestion of the Secretary of Commerce, and consisted of representatives of the War, Navy, Agricultural, Interior, Post Office, Treasury, and Commerce Departments, the Railroad Administration, the Panama Canal, and the Educational Bureau of the Paint Manufacturers' Association of the United States. The committee submitted a preliminary draft of the specification to a large number of representatives of the paint and varnish industries, including the manufacturers of zinc oxide, and gave careful consideration to the replies received in time.

[4] Circular No. 87.

CONTRAST SENSIBILITY OF THE EYE.[5]

By Enoch Karrer and E. P. T. Tyndall.

[ABSTRACT.]

A KNOWLEDGE of the contrast sensibility of the eye is very essential to the proper understanding of the theory and use of Searchlamps and Searchlight Illumination.

The searchlamp is used at night when the eye is generally adapted to low levels of illumination. If the observer is far removed from the searchlamp the illumination may be simply that from the moon and sky. If he is near the lamp, however, he must look through the diffused light along the beam.

In order to be visible, the target must be illuminated to a degree that will make sufficient contrast in brightness or color between it and this surrounding field. Data are given showing the relationship that exists between the brightness and the size of the target and the brightness of the surrounding field.

In these experiments a large surface painted white was illuminated with an incandescent lamp. The target consisted of a rectangular spot of this surface more brightly illuminated by means of a projection lantern, equipped with a simple bilateral slit. The image of the slit determined the boundaries of the test spot or "target," the length of which could be varied by varying the slit width. Precautions were taken to have the brightness across the image of the slit uniform. The brightness of either the test spot or field could be varied by means of sectored discs, so that any desired contrast between them could be obtained for any given brightness of field.

Curves are given showing relation between length of test spot and the brightness of the field for various contrasts, and also curves showing relationship between the length of test spot and contrast between field and spot for various values of the field brightness.

TURBIDITY STANDARD OF WATER ANALYSIS.[6]

By P. V. Wells.

[ABSTRACT.]

THE amount of suspended matter in water is estimated by its turbidity, hence, a reliable standard of turbidity is necessary.

[5] Scientific Paper No. 366.

[6] Scientific Paper No. 367.

To develop such a standard was the object in view when this investigation was undertaken.

The optical principles of turbidity and the results obtained by classic theories on the subject are summarized. Various methods in vogue for measuring turbidity have been repeated with the purpose of determining their comparative reliability. Turbidity standards from a number of water laboratories were obtained and compared. Tentative suggestions are given for avoiding the large variation between standards which was found.

RECOMMENDED SPECIFICATIONS FOR LEADED ZINC OXIDE, DRY AND PASTE.[7]

[ABSTRACT.]

PREPARED and recommended by the U. S. Interdepartmental Committee on Paint Specification Standardization, January 12, 1920. This committee was appointed at the suggestion of the Secretary of Commerce, and consisted of representatives of the War, Navy, Agricultural, Interior, Post Office, Treasury, and Commerce Departments, the Railroad Administration, the Panama Canal, and the Educational Bureau of the Paint Manufacturers' Association of the United States. The committee submitted a preliminary draft of the specification to a large number of representatives of the paint and varnish industries, including the manufacturers of leaded zinc oxide, and gave careful consideration to the replies received in time.

RECOMMENDED SPECIFICATIONS FOR TURPENTINE (GUM SPIRITS AND WOOD TURPENTINE).[8]

[ABSTRACT.]

PREPARED and recommended by the U. S. Interdepartmental Committee on Paint Specification Standardization, October 27, 1919. This committee was appointed at the suggestion of the Secretary of Commerce, and consisted of representatives of the War, Navy, Agricultural, Interior, Post Office, Treasury, and Commerce Departments, the Railroad Administration, the Pan-

[7] Circular No. 88.
[8] Circular No. 86.

ama Canal, and the Educational Bureau of the Paint Manufacturers' Association of the United States. The Committee submitted a preliminary draft of the specification to a large number of representatives of the naval stores industries and the paint and varnish industries, and gave careful consideration to the replies received in time.

Tests of Dopes and Fabrics. (*Aircraft Technical Note, Bureau of Construction and Repair, Navy Department.*)—Dopes made from cellulose acetate have for some time been given preference in aircraft work, though more expensive than those made from the cellulose nitrate. The former product requires the use of acetic acid and acetic anhydride in its manufacture, which chemicals are costly and needed for other important industries. It has been found that the admixture of from 5 to 8 per cent. of ammonium phosphate or ammonium magnesium phosphate to the nitrate adds material fire-resistance properties. The subject of non-inflammable fabrics has also been studied, samples having been submitted for the purpose. It was found that these had been prepared by impregnation with ammonium phosphate. These fabrics are measurably fire-resisting, since when ignited a notable amount of ammonia is evolved, which quenches the flame.

H. L.

Waterproof Finishes. (*Aircraft Technical Note, Bureau of Construction and Repair, Navy Department.*)—The Forest Service has recently been experimenting with the waterproofing properties of wood-finishing preparations. Among other articles, a phenol condensation resin was tried, which was very efficient, but difficult to apply, as the wood must be well dried. Paraffin and beeswax, followed by varnishing, did not afford protection, and coating with metals by the spraying methods was also unsatisfactory, especially as it is likely that the coating will be torn by the centrifugal force developed in the rotation of the propeller. Good results, however, were obtained by filling the wood, varnishing, coating with the liquid used for making gold size, and then applying aluminum leaf. After drying, the surface is varnished with a highly waterproof varnish. Aluminum leaf is preferred on account of toughness. Experiments were made by coating electrolytically with copper. This makes a good resistance, but the metal does not adhere well. Good results were obtained with hard rubber (about 3 mm. thick). Good spar varnish, especially when four coats are used, gives excellent results, which are markedly improved by adding enamel, which indicates the advisability of using such enamel paints instead of plain varnish in all constructions exposed much to moisture.

H. L.

NOTES FROM THE RESEARCH LABORATORY EASTMAN KODAK COMPANY.*

NEW TURBIDIMETER FOR SOLUTIONS OF GELATINE, CELLULOSE, VARNISHES, ETC.[1]

By S. E. Sheppard.

A TURBIDIMETER for definite thickness of fluid is described. It is based on the continuously variable visibility of a standard object, consisting of two crossed gratings which can be rotated in opposite directions about a common axis. It is shown that for the practical limits of working if A_{max} be the angle for the visibility limit for any standard medium, *e.g.*, distilled water, lacquer solvent, etc., and if A be the angle for the same thickness of turbid solution, then putting $A_{max}, /A = 100/C$, the percentage clarity C. is obtained, $= 100\ A/A_{max}$.

The advantages of using per cent. clarity figures, instead of arbitrary turbidity figures, are emphasized, and the technic for use of very viscous solution with volatile solvents discussed.

CHEMICAL INDUCTION IN PHOTOGRAPHIC DEVELOPMENT. I. INDUCTION AND THE WATKINS' FACTOR.[2]

By S. E. Sheppard and G. Meyer.

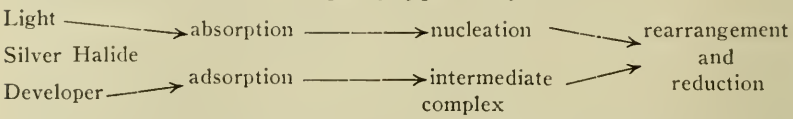
THE Lainer effect, which consists in the acceleration of development by dilute solutions of soluble iodides has been investigated quantitatively and found to affect chiefly organic developers of low reduction-potential, such as hydroquinone. Such developers, having a low Watkins factor, show a marked induction period; it is now shown that this is reduced by soluble iodide, the principal action of which is to increase the Watkins factor. The action is discussed in connection with the mechanism of development. Evidence is brought forward against Lüppo-Cramer's theory of "nucleus activation," and in support of the view that

* Communicated by the Director.

[1] Communication No. 81 from the Research Laboratory of the Eastman Kodak Company, published in *J. Ind. Eng. Chem.*, 1920, p. 167.

[2] Communication No. 84, published in *Phot. J.*, 1920, p. 12.

the action depends upon increased adsorption of the developing agent. The bearing of this view, including the possibility of a solid complex formation between developer and silver halide on the mechanism of development is discussed, the modification consisting in regarding the photo-chemical action of light and development as a process of coupling typified by:



In addition there is a fogging action of dilute iodide solutions, on silver bromide emulsions, which is ascribed to nucleus infection of the grain.

Technical Applications of Ethyl Chloride are described by ALBERT HENNING in *Journal of the Society of Chemical Industry, Transactions,* 1920, xxxix, 1–8. Commercial ethyl chloride has a high state of purity, it is not poisonous, and is not more inflammable than methylated spirit or benzine. High pressure apparatus is not required in its use, since its gauge pressure is only 12 pounds per square inch at a temperature of 30° C. Ethyl chloride is used as an ethylating agent in the manufacture of dyestuffs and pharmaceutical products, as a solvent, as a refrigerant, and as an anæsthetic, either local or general. On the basis of its ethyl content, ethyl chloride is the cheapest ethylating agent; when used for such a purpose in an autoclave, the stuffing-box of the latter should be provided with asbestos packing impregnated with glycerin. Ethyl chloride is a good solvent for fats, oils, and simple organic compounds, and may be used for their extraction. Organic compounds which contain several hydroxyl groups are dissolved to but a slight extent, if at all. A solid is obtained in crystalline form from its solution by cooling that solution; if the solvent be ethyl chloride, the crystals may be obtained by evaporation of the solvent under reduced pressure, for the temperature of the solution then falls to −15° or −20° C. Ethyl chloride is the best refrigerant for household machines, since it may be used at a low pressure, not exceeding 15 pounds per square inch. It is also used for this purpose in large machines on both land and ships. In chemical manufacture, when refrigeration is required, ethyl chloride may be used as the refrigerant, since it may be circulated directly through the apparatus; and circulation of cooled brine is entirely eliminated. When a spray of ethyl chloride is directed on a small object, the temperature of the latter may be reduced as low as −30° C.

J. S. H.

NOTES FROM THE LABORATORY, GENERAL ELECTRIC COMPANY.*

THEORY OF UNIMOLECULAR REACTION VELOCITIES.

By Saul Dushman.

For some time Dr. Langmuir and the writer have been working over the material for a paper on the velocity of chemical reactions. In the course of the discussion of this subject, more especially in the consideration of the radiation theory recently suggested by W. C. McC. Lewis, it occurred to the writer that in the case of unimolecular gas reactions, *e.g.*, the dissociation, $H_2 \rightarrow 2H$, a formula could be deduced for calculating the rate of reaction, which is much simpler than the purely empirical relation proposed by Lewis.

Assuming that the rate of dissociation of a gas A_2, at any instant, is porportional to the concentration of the gas in the undissociated (or molecular) state, we can express this assumption by means of the relation,

$$\frac{-dn}{dt}2 = k_2 n_2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

n_2 = number of undissociated molecules per unit volume.
k_2 = reaction-velocity constant at the given temperature.

Since this relation means that the *fraction* of A_2 converted into the atomic state during any interval of time is independent of the concentration, it must therefore follow, as pointed out by Perrin, that the rate of dissociation is not dependent upon the frequency of collision between molecules of A_2. In other words, the value of k_2 in the above equation must be dependent only upon the *temperature* and the *internal structure* of the molecule.

The dimension of k_2 is t^{-1}, and does not involve either mass or volume. Furthermore, from the fact that the rate of dissociation cannot be infinitely great, it is evident that only a certain fraction of the molecules must be capable of dissociating at any instant, that is, are in the "active state." Since k_2 increases with the temperature, we can assume that the value of this fraction

* Communicated by the Director.

also increases (at the same rate as k_2) with the temperature. Following the considerations developed by Marcelin, Rice and Lewis. we can express the value of this fraction, $\propto$, at any temperature, T, by means of the reaction

$$\propto = e^{-Q/RT}$$

where Q = heat of dissociation per mol A_2, and e and R have their usual signification.

Thus k_2 contains both $\propto$ and a number which has the dimensions t^{-1}. Now, let us assume firstly that we can write $Q = Nh\nu$ (Haber, Lewis, etc.), where $N = 6.062 \times 10^{23}$ (the number of molecules per mol), h is Planck's constant, and ν is some vibration-frequency. Since $R/N = k = 1.372 \times 110^{-16}$ ergs/deg., we thus obtain the relation,

$$\propto = E^{-h\nu/kt}$$

Since ν has the dimensions t^{-1}, we shall now make a second assumption that the value of the disssociated constant k_2 is given by the relation

$$k_2 = \nu e^{-h\nu/kT} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

$$\frac{Q}{Nh} e^{-\frac{Q}{RT}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

In other words, the rate at which the molecules A_2 dissociate depends *only upon the heat of dissociation and the temperature.* The exact significance of this equation will be discussed more fully in the paper to be published shortly by Dr. Langmuir and the writer. That it has some kind of universal significance follows from Dr. Langmuir's observation that equation (3) is also applicable to the phenomena of evaporation and electron emission. Evidently it adds more mystery to the significance of the quantum constant h. Such discussion must, however, be postponed for the more comprehensive paper on this subject.

So far as the writer is aware, the only unimolecular reaction whose velocity constant has been measured directly is the dissociation of PH_3, for which, according to Trantz (*Z. S. f. anorg. Chem.* 106, 95, 1919), the value of k_2 at $T = 495$, is 10.2×10^{-3}, while Q has a value between 70,000 and 80,000 calories. By means of equation (3) and using the above value of k_2, we obtain the result $Q = 72{,}800$. The agreement is thus very satisfactory in this case.

The validity of equation (3) may, however, be checked indirectly from determinations of the equilibrium constants and consideration based on the kinetic theory of gases, as follows:

Let n_1 denote the number of atoms per unit volume at any instant. Then the rate of combination is given by the number of collisions. If it is assumed, as seems reasonable, that every collision between atoms results in the formation of a molecule, we derive the equation

$$\frac{dn_2}{dt} \sigma^2 n_1^2 G \sqrt{\frac{4}{3} \pi} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

where

σ = molecular (or atomic) diameter.

G = root mean square velocity of atoms

$= \sqrt{\frac{3RT}{M}}$

M = Atomic weight.

Hence,

$$\frac{dn_2}{dt} = \sigma^2 n_1^2 \sqrt{\frac{4\pi RT}{M}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4a)$$

If c_1 and c_2 denote concentration in mols per cm^3 of the dissociation products and undissociated substances, respectively, we have the ordinary relations,

$$\frac{-dc_2}{dt} = k_2 c_2$$

$$\frac{dc_2}{dt} = k_1 c_1^2$$

Since $c_2 = n_2/N$, and $c_1 = n_1/N$, *it* follows that the equilibrium constant,

$$K = \frac{c_1^2}{c_2} = \frac{k_2}{k_1} = \frac{Qe^{-Q/RT}}{N^2 h \sigma^2 \sqrt{\frac{4\pi RT}{M}}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

In the case of H_2 and I_2, the equilibrium constants for the dissociation into atoms are known with a fair degree of accuracy. Data are also available for Br_2 and Cl_2, the last mentioned being very inaccurate. The following table gives the values of Q calculated by means of equation (5) from the observed values of K at different temperatures for each gas. The last column gives

the most reliable values of Q as derived from the temperature-coefficients of the equilibrium constant K. It is evident that the agreement is very satisfactory.

Gas	$10^5 \times \sigma$	T	Q calc.	Q obs.
H_2	2.0	2000	89,600	87,000
I_2	4.52	1073	36,300	36,000
Br_2	3.74	1000	46,600	46,160
Cl_2	3.30	1940	86,900	(86,000)

The Thermal Conductivity of Solid Insulators. W. M. THORNTON. (*Phil. Mag.*, December, 1919.)—An inspection of the measured values of the heat conductivity of insulators leads him to conclude that this quantity is equal numerically to the product of the coefficient of elasticity concerned in the propagation of sound by the density of the substance. He tabulates the three quantities: (*a*) heat conductivity; (*b*) product of coefficient of elasticity by density, and (*c*) square of the product of velocity of sound by density (this should equal the second of the three quantities by the known relation—velocity of sound equals the square root of elasticity divided by density) for quartz, various kinds of glass, graphite, marble, mahogany, deal, ice, paraffin wax. The agreement is striking. For India rubber and for cork, however, the rule breaks down. The author draws the conclusion: "The chief practical qualification of a material as a heat insulator is that it should be light and inelastic."

G. F. S.

Preparation of Arsenic Trichloride from White Arsenic and Phosgene.—L. H. MILLIGAN, W. A. BAUDE, and H. G. BOYD (*Journal of Industrial and Engineering Chemistry*, 1920, xii, 221–223) of the Edgewood Arsenal have prepared arsenic trichloride on both a laboratory and a commercial scale by the reaction between arsenious oxide (white arsenic) and carbonyl chloride (phosgene) in the presence of carbon as a catalyst. The carbonyl chloride, which is a gas, may be used as such or mixed with air; it is passed over a mixture of white arsenic and carbon which is heated to a temperature above 175° C., usually 200° to 260° C. The arsenious chloride, which is formed, is recovered from the resulting gases by passing them through a condenser. The yield is almost quantitative. Carbon dioxide is the other product of the reaction. It is suggested that this reaction of phosgene may possibly be used for the preparation of other inorganic chlorides.

J. S. H.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

THE HEPTOSES FROM GULOSE AND SOME OF THEIR DERIVATIVES.[1]

By F. B. LaForge.

[ABSTRACT.]

THE two epimeric guloheptonic acids were obtained by the cyanhydrin synthesis from pure gulose, and separated by converting them into their barium salts. The barium salt of the alpha acid, being crystalline and difficultly soluble in water, was easily purified. From the barium salt, the free acid was prepared as an uncrystallizable syrup. The phenylhydrazid was prepared and found to melt at 191°. It showed $(\alpha)_D^{20} = -15.4$. The syrupy acid, when reduced in the usual manner with sodium amalgam, yielded crystalline alpha guloheptose of the following properties: M. P. 185°–187°, uncorr. $(\alpha)_D^{22} = -65.65$. It was much less soluble in water than most sugars.

Upon further reduction of the sugar, alpha guloheptitol was obtained (M. P. 138°–141°). It showed a slight dextro rotation in borax solution.

This compound is identical with beta guloheptitol obtained by Pierce (*J. Biol. Chem.*, 23:327).

The compounds of the beta series were prepared from beta guloheptonic acid, which remained as the barium salt in solution after the crystallization of the alpha compound.

The free acid which still contained some of the alpha derivative was reduced with amalgam and freed from sodium salts by means of alcohol. The resulting mixture of beta guloheptose, together with some of the alpha sugar and some of the unreduced acid, was mixed with glacial acetic acid in which the alpha compound is almost insoluble. By this means a syrup containing almost no alpha sugar was obtained. Upon reduction of the resulting mixture with amalgam it was possible to prepare a syrup which yielded the benzal derivative of beta guloheptitol. From the

* Communicated by the Chief of the Bureau.

[1] Published in *J. Biol. Chem.* 41, 251, 1920.

purified benzal derivative the beta heptitol was obtained by hydrolysis. This compound melted at 128°–129° uncorr., and showed an optical activity too small to be measured.

THE ARSENATES OF CALCIUM: I. EQUILIBRIUM IN THE SYSTEM ARSENIC PENTOXIDE, CALCIUM OXIDE, WATER AT 35° (ACID SECTION).[2]

By C. M. Smith.

[ABSTRACT.]

CALCIUM arsenate has recently become important as an agricultural spray material, particularly in connection with the fight to control the boll weevil in the southern cotton fields.

Owing to the harmful action of so-called "soluble arsenic" on plant tissues, it is necessary to know in detail the action of water on any arsenical spray material. In this case a general study of the system As_2O_5, CaO, H_2O at 35° was attempted. The present paper covers only the range in which the solutions are acid to phenolphthalein.

Numerous empirical mixtures of the three components were made. After agitation for a suitable period, these were filtered, and both filtrates and wet residues analyzed. Graphical analysis then led to a knowledge of the composition of the solid phases. Finally the results were interpreted in terms of the phase rule criteria.

Three compounds have been found to exist in the region investigated. Dicalcium arsenate monohydrate, $CaHAsO_4.H_2O$, which occurs in nature as the mineral Haidingerite, exists in contact with solutions which vary almost linearly from 0.10 per cent. CaO, 0.20 per cent. As_2O_5 to 6.8 per cent. CaO, 27.5 per cent. As_2O_5. The latter is the invariant point at which the second solid phase, monocalcium arsenate $CaH_4(AsO_4)_2$, appears. This monocalcium arsenate is stable in contact with solutions which vary approximately linearly from the above-mentioned invariant point to another invariant point at 0.11 per cent. CaO, 72 per cent. As_2O_5. Here the third solid phase, $3As_2O_5.5H_2O$, makes its appearance. The arsenic in solution at the second invariant point agrees quite well with the solubility of the hydrate $3As_2O_5.5H_2O$ as determined by other investigators (Menzie and Potter).

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[2] Published in *J. Am. Chem. Soc.*, 42, 259, 1920.

A graph given in the JOURNAL article shows the various relationships mentioned here, and permits of the prediction of the behavior of any empirical mixture of As_2O_5, CaO and H_2O within the region investigated.

ALKALI FUSIONS: I. THE FUSION OF SODIUM p-CYMENE SULFONATE WITH SODIUM HYDROXIDE FOR THE PRODUCTION OF CARVACROL.[3]

By H. D. Gibbs and Max Phillips.

[ABSTRACT.]

AN apparatus which is particularly well adapted to the study of alkali fusions has been devised in the Bureau of Chemistry. It consists of a bath of melted tin-lead alloy, properly insulated and heated by means of gas. The temperature of the bath can be maintained very nearly constant. The mixture to be fused is placed in six fusion tubes, made of heavy steel and provided with screw caps and copper gaskets, which can be screwed down until they are gas-tight. A system of racks and gears makes it possible to lower the tubes, which are firmly held on a carrier, into the bath. These tubes are revolved by means of an electric motor through a proper mechanical device, the tumbling motion thus imparted mixing the molten contents thoroughly. With this apparatus six points on a curve may be obtained in one run.

Using this apparatus, a study was made of the yield of carvacrol obtained when sodium cymene sulfonate is fused with sodium hydroxide. In order to determine the optimum conditions for obtaining the highest yield of carvacrol, it was necessary to study the following factors which influence the yield: (1) Proper fusion temperature; (2) proper fusion period; (3) ratio of sodium hydroxide to the sodium cymene sulfonate; (4) relation between the carvacrol yield and the percentage of water in the charge.

The results obtained show that the best yield (75 per cent.) of carvacrol was obtained when the fusion was conducted at 350° C. When fused at this temperature, six hours seemed to be the optimum fusion period. So far as the sodium hydroxide is concerned, a little more than the theoretical amount should be used,

[3] Published in *J. Ind. Eng. Chem.*, 12, 145, 1920.

2.2 moles sodium hydroxide to 1 mole of sodium cymene sulfonate being sufficient. The presence of an appreciable amount of water in the fusion mixture tends to reduce somewhat the carvacrol yield. When water is added to the charge to the extent of 50 per cent. of the sodium hydroxide used, the fusion period should be increased to ten hours in order to secure the best yield.

The Revival of the Myth about Gunfire. SIR NAPIER SHAW. (*Quarterly Journal, Royal Meteorol. Soc.*, April, 1919.)—In an address before the Society its president says: "And, by way of parenthesis, it would seem that the Queen of the Air, the Goddess of Wisdom, according to the Greeks, sometimes makes merry at mortals' expense. During the war there was a good deal of arguing upon the time-honored subject of the influence of gunfire upon the weather. With the signing of the Armistice on November 11, 1918, there came a spell of calm fine weather, so that once more it became—shall I say apparent?—that with the cessation of gunfire came the repose of the elements, which, as some vigorous writers would have us believe, were under the control of our enemies' artillery. And then as the period of the Armistice went on and the guns, now mute, passed forward towards the East, like so many other things that have to do with the weather, there came upon us a succession of dismal dripping days, the like of which we may not wish to see again, but assuredly we shall, guns or no guns, if we live long enough; and once more we can assert that whatever else it may be that controls the weather, it certainly is not the absence of gunfire."

G. F. S.

The Lunar Tide in the Earth's Atmosphere. S. CHAPMAN. (*Quarterly Journal, Royal Meteorol. Soc.*)—From the time of Bernoulli and D'Alembert such tides have been considered. The author presents the results of a discussion of long series of records of barometric pressures from Batavia and Hongkong. The conclusions are: (*a*) The period of the lunar tide as shown in barometer readings is purely semidiurnal; (*b*) the amplitude of the variation in barometric reading is independent of the hour angle between sun and moon; (*c*) the data give no conclusive result as to the influence of the moon's distance; (*d*) there is a distinct seasonal variation affecting both amplitude and phase of the tide; (*e*) there is a rapid decrease of amplitude with departure from the equator.

At the equator the semi-amplitude of the lunar atmospheric tide is .084 millibars or .063 millimetres of mercury, which is 2.3 times as great as that predicted in Lamb's hydrodynamics.

G. F. S.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting held Wednesday, March 17, 1920.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 17, 1920.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership since last report, 7.

Reports of progress were presented by the Committee on Library and the Committee on Science and the Arts.

After the transaction of the above business the meeting became a joint one with the Philadelphia Section of the American Institute of Electrical Engineers, and the President requested Prof. C. E. Clewell, Chairman, to preside.

Mr. G. H. Clamer, of Philadelphia, presented the paper of the evening on "The Induction Electrical Furnace." The development of the induction furnace was traced, in its various forms, from its original conception by Colby of the single-turn, open-ring type furnace, to the latest developments by Dr. E. F. Northrup in the use of high frequency induction heating. The various fluid motions due to electro-dynamic forces were described, and the use which is made of such forces in several forms of induction furnaces was pointed out. Particular attention was given to the commercial operation of induction furnaces, using both low and high frequency currents. The subject was illustrated by numerous lantern slides. After a brief discussion a rising vote of thanks was extended to the speaker.

Adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, March 3, 1920.)

HALL OF THE INSTITUTE,
PHILADELPHIA, March 3, 1920.

MR. CHARLES PENROSE *in the Chair.*

The following reports were presented for final action:

No. 2733. CO_2 and Draft Recorder. The Certificate of Merit awarded to Joseph W. Hays and Charles W. Hays, of Baltimore, Maryland.

No. 2742: Recording Devices. The Edward Longstreth Medal of Merit awarded to Morris E. Leeds, of Philadelphia.

No. 2755: The Franklin Medal Awards. The Franklin Medal awarded to Sir Charles Algernon Parsons and Prof. Svante August Arrhenius.

The following report was presented for first reading:

No. 2757-2758: Literature Award.

R. B. OWENS,
Secretary.

SECTIONS.

Mechanical and Engineering Section.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, February 26, 1920, at 8 o'clock. In the absence of the Chairman of the Section, Dr. Walton Clark, President of the Institute, called the meeting to order. Major General C. C. Williams, Chief of Ordnance, U. S. Army, War Department, Washington, D. C., presented a communication entitled "Artillery of the A. E. F." A description was given of the various types of artillery equipment used by the American Expeditionary Force in France, with a brief discussion of their uses and the reasons for their adoption. The subject was illustrated by lantern photographs of guns and equipment used by the several allied forces.

After a brief discussion the thanks of the meeting were extended to the speaker.

Adjourned.

ALFRED RIGLING,
Acting Secretary.

Sections of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, March 4, 1920, at 8 o'clock. The minutes of the joint meeting of February 5, were read and approved.

Henry S. Washington, Ph.D., Petrologist in the Geophysical Laboratory of the Carnegie Institution, Washington, D. C., delivered a lecture on "The Chemistry of the Earth's Crust." Among the subjects discussed were the homogeneity or heterogeneity of the earth's crust, the general quantitative occurrence of the various chemical elements in the crust, the average chemical composition of the igneous rocks, and their distribution in petrographic provinces. Attention was also paid to certain mutual relations between certain elements with special reference to the occurrence of ores and minerals, and the metabolism of plants and animals.

The communication was discussed by Drs. Kemp, Creighton, Keller, and Washington; Messrs. Quimby and Penrose, and others. On motion of Dr. Creighton, seconded by Mr. Penrose, a vote of thanks was tendered Dr. Washington. The meeting then adjourned.

JOSEPH S. HEPBURN,
Secretary.

Section of Physics and Chemistry.—A joint meeting of the Section and the Physics Club was held in the Hall of the Institute on Thursday evening, March 11, 1920, at 8 o'clock. Dr. George A. Hoadley on behalf of The

Franklin Institute, and Dr. Thomas D. Cope on behalf of the Physics Club, presided jointly. The minutes of the previous meeting were read and approved.

Dayton C. Miller, Sc.D., Professor of Physics in the Case School of Applied Science, Cleveland, Ohio, delivered a lecture on "Photographing Sound Waves from Large Guns and Projectiles." An account was given of an extended series of experiments conducted at several Proving Grounds, with the coöperation of the Ordnance Department of the United States Army, concerning the pressure, velocity and form of the sound-waves produced by the discharge of guns of large calibre, from 10 to 14 inches. The pressure field was studied by means of a new type of baroscope. The variation in the velocity of the explosive sound from the muzzle to a distance of several miles was determined by means of special microphones in connection with a string galvanometer and a recording device. A new portable phonodeik was used to photograph both the sound wave proper and the crack produced by the motion of the projectile. The lecture was illustrated by experiments and lantern slides.

The paper was discussed by Doctors Hoadley, Stradling, Miller and others. On motion of Dr. Walton Clark a vote of thanks was tendered Doctor Miller. The meeting then adjourned.

JOSEPH S. HEPBURN,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(*Stated Meeting, Board of Managers, March 10, 1920.*)

RESIDENT.

MR. FRANCIS SHUNK BROWN, Lawyer, 1005 Morris Building, Philadelphia, Pa.

PROF. C. E. CLEWELL, Assistant Professor of Electrical Engnieering, University of Pennsylvania, and for mail, 4919 Osage Ave., Philadelphia, Pa.

MR. JACOB SCHORR, Production Manager, Greenwald Brothers, 9th and Spruce Sts., Philadelphia, Pa.

MR. IRA JEWELL WILLIAMS, Lawyer, 1005 Morris Building, Philadelphia, Pa.

PROF. WINTHROP ROBINS WRIGHT, Teacher, Department of Physics, Swarthmore College, and for mail, 4 Whittier Place, Swarthmore, Pa.

ASSOCIATE.

MR. JUSTO LOPEZ NAVARRO, Electrical Engineer, Philippine Engineering Co., and for mail, 121 L. Guerrero, Ermita, Manila, P. I.

MR. DAVID H. WILSON, Student, 640 North 32nd St., Philadelphia, Pa.

CHANGES OF ADDRESS.

COL. GEORGE H. EMERSON, Chief of Motive Power and Equipment, Baltimore and Ohio Railroad Company, Baltimore, Md.

MAJOR WILLIAM J. HAMMER, Hotel Earle, 103 Waverly Place, New York City, N. Y.

MR. FREDERIC V. HETZEL, P. O. Box 366, West Chester, Pa.
MR. R. L. O'DONNEL, Vice President, Pennsylvania Railroad Company, 903 Pennsylvania Station, Pittsburgh, Pa.
MR. H. R. VANDEVENTER, 206 Church Street, Sumter, S. C.

NECROLOGY.

Reuben Haines was born in Germantown, Philadelphia, in 1851, and died on February 18, 1920.

He was educated at Haverford College and the University of Pennsylvania, receiving from Haverford College the degrees of Bachelor of Arts in 1871 and Master of Arts in 1878.

Mr. Haines conducted a Chemical Laboratory for many years, and devoted considerable attention to water analysis. He was very active in the Chemical Section of the Institute, and contributed about a dozen articles to the JOURNAL, chiefly on water and water analysis. He also devoted considerable time to the subject of photography and collected a large number of negatives of places of historic interest near his home. He was a member of the American Chemical Society, the Society of Chemical Industry and a number of organizations devoted to the study of history and the natural sciences.

He became a member of the Institute in October, 1874.

Mr. Charles Abel, 300 Fifth Avenue, Haddon Heights, N. J.

Mr. C. M. Bunting, Comptroller, Pennsylvania R. R. Co., Broad Street Station, Philadelphia, Pa.

LIBRARY NOTES.

PURCHASES.

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American Society for Testing Materials.—Proceedings, vol. 19. 1919.
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Conversations on Chemistry.—2 vols. 1822.
DOOLEY, W. H.—Applied Science for Metal Workers. 1919.
HASKELL, A. C.—How to Make and Use Graphic Charts. 1919.
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Industrial Arts Index.—7th Annual Volume. 1918–1919.
MARKHAM, E. R.—Tool-Making. 1919.
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MÜLLER, N. L.—Fabrikation und Eigenschaften der Metalldrahtlampen. 1914.
National Association of Cement Users.—Proceedings. Vol. xv. 1919.
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Photograms of the Year.—Annual Review. 1919.
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RIDGWAY, ROBERT.—Color Standards and Color Nomenclature. 1912.
SMITH, J. R.—The World's Food Resources. 1919.
STRACHAN, JAMES.—Recovery and Re-manufacture of Waste Paper. 1918.

TINKLER, C. K., and CHALLENGER, F.—Chemistry of Petroleum and its Substitutes. 1919.

GIFTS.

Allis-Chalmers Manufacturing Company, Bulletin No. 1104. Milwaukee, Wis., 1919. (From the Company.)

American Cement Machine Company, Catalogue No. 920. Keokuk, Iowa., no date. (From the Company.)

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Archer Iron Works Company, Catalogue No. 20. Chicago, Ill., no date. (From the Company.)

Austin-Western Road Machinery Company, Catalogue No. 18. Chicago, Ill., no date. (From the Company.)

Ballard, Frank E. Company, Catalogue of Automatic Pressure and Temperature Controlling Devices. Bridgeport, Conn., no date. (From the Company.)

Boston Pressed Metal Company, Catalogue, The Possibilities of Pressed Metal Engineering. Worcester, Mass., no date. (From the Company.)

Braun, C. F., Company, Catalogue "A." San Francisco, Cal., 1919. (From the Company.)

Canada Department of Mines, Summary Report for the year 1918. Ottawa, 1920. (From the Department.)

Canada Engineering Institute, Charter, By-Laws, List of Members, and Roll of Honour, 1919. Montreal. (From the Institute.)

Chicago Flexible Shaft Company, Catalogue No. 75. Chicago, Ill., no date. (From the Company.)

Coatesville Boiler Works, General Catalogue No. 24. Coatesville, Pa., no date. (From the Works.)

Colgate University, Annual Catalogue, 1919–1920. Hamilton, N. Y., 1920. (From the University.)

Columbus Bolt Works Company, Catalogue of Columbus Bolts and Nuts. Columbus, Ohio, 1919. (From the Company.)

Concrete Engineering Company, Handbook of Fieproof Construction. Omaha, Neb., no date. (From the Company.)

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Crouse-Hinds Company, Catalogues Nos. 201 and 202. Syracuse, N. Y., 1917. (From the Company.)

Curtis Pneumatic Machinery Company, Catalogue No. 63. St. Louis, Mo., no date. (From the Company.)

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Edgemont Machine Company, Inc., Catalogue "G." Dayton, Ohio, no date. (From the Company.)

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Ferdinand, L. W., and Company, Booklet, Seaplane Float Construction. Boston, Mass., no date. (From the Company.)

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Garrison Machine Works, Catalogue of Gear Chucks. Dayton, Ohio, 1920. (From the Works.)

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Golden-Anderson Valve Specialty Company, Catalogue No. 20. Pittsburgh, Pa., no date. (From the Company.)

Herbert, Alfred, Ltd., Bulletin No. 51. New York, N. Y., 1919. (From the Company.)

Hergi Manufacturing Company, Bulletins Nos. 10 and 13. Bridgeport, Conn., no date. (From the Company.)

Huther Brothers Saw Manufacturing Co., Catalogue No. 38. Rochester, N. Y., 1917. (From the Company.)

Illinois Stoker Company, Catalogue "K." Alton, Ill., no date. (From the Company)

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Skandia Pacific Oil Engine Company, Catalogue of Skandia Oil Engines. San Francisco, Cal., no date. (From the Company.)

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Standard Paint Company, Booklet, Preservative Coatings. New York, 1918. (From the Company.)

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Theorie et Usage de la Regle A Calculs par P. Rozé. Paris, France, 1907. (From Mr. L. E. Picolet.)

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University of Pittsburgh, General Catalogue 1918–1919. Pittsburgh, Pa., 1919. (From the University.)

Vassar College, Fifty-Fifth Annual Catalogue, 1919–1920. Poughkeepsie, N. Y., 1920. (From the College.)

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Wheeler Condenser and Engineering Company, Bulletin No. 112-B. Carteret, N. J., 1919. (From the Company.)

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Wireless Specialty Apparatus Company, Catalogue of Radio Equipment. Boston, Mass., 1919. (From the Company.)

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BOOK NOTICES.

ACCOUNTS RENDERED OF WORK DONE AND THINGS SEEN. By J. Y. Buchanan, M.A., F.R.S. 8vo, 435 pages, illustrated. Cambridge, at the University Press, 1919, New York, G. P. Putnam's Sons, price $6.75.

With a table of contents containing elaborate summaries of the several articles, and no index, this book is distinctly unconventional. It is, as the title indicates, a reprinting of essays and observations made by the author during many years of an active and useful life. His main interest is in oceanography. He is Commandeur de l'Order de St. Charles de Monaco. Most of the papers are supplemented by notes or appendices bringing the discussion up to date. All the articles make interesting reading. The versatility of the author will be clearly indicated by a summary of the several titles: Geography; its physical and economical relations (1889). A retrospect of oceanography in the twenty years before 1895 (1895). On similarities in the physical geography of the great oceans (1886). Relations of the temperature of the sea to that of the air above (1885). Color of the sea (1910). On the occurrence of sulphur in marine mud and nodules (1890). Note on manganese nodules found on the bed of the ocean (1877). Manganese nodules in Loch Fyne (1877). On the composition of oceanic and littoral nodules (1891). On a method of determining the specific gravity of soluble salts, etc. (1906). The Mediterranean Sea (reprint from 9th ed., *Encyc. Brit.*). On the composition of some deep sea deposits from the Mediterranean (1891). On the oxidation of ferrous salts (1881). The sunsets of autumn, 1883 (1883). Sur le densité et l'alcalinité des eaux de l'Atlantique et de la Méditerranée (1893). Monaco a whaling station (1896). The cruise of the *Princess Alice* (1902). The sperm whale and its food (1896). The oceanographic museum at Monaco (1910). Lakes (1882). On the distribution of temperature in Loch Lomond during the autumn of 1885 (1885). The winding of rivers (1907). Volcanoes and earthquakes (1872). On a remarkable effect produced by the momentary relief of great pressure (1903). Preliminary note of the compressibility of glass (1880). On the compressibility of solids (1904). On an apparatus for gas analysis (1874). Airtight subdivisions for ships (1889). The Northallerton accident (1894). The wreck of *Santos Dumont No. 6* (1902). The daintiness of the rat (1911). This paper gives an account of the peculiar selections of tissues of lemons and mandarin oranges by "forest rats" in a garden at Bordighera. The last paper is: On fish and drought (1911).

The book will furnish entertainment for many an hour to those interested in general science. It is well printed and numerously illustrated.

HENRY LEFFMANN.

TIDAL LANDS—A STUDY OF SHORE PROBLEMS. By Alfred C. Carey and Francis Wall Oliver. 248 pages, illustrations, 8vo. New York, D. Van Nostrand Company, 1919. Price, $5.00.

The Franklin Institute has recently acquired a copy of the above work, and in view of the destructive agencies which have been preying upon our coasts this work is a timely compendium, by experts, of the various efforts which have been made in foreign countries to protect riparian lands from those ceaseless physical forces. It is impossible to do justice to it in this brief notice, but the subject is treated in all its phases not only as a public utility, but from an engineering, botanical and physical aspect. Citations of failures and their causes are recorded as pointing the road to success—groynes, bulkheads, aprons, planting, drainage, etc., are carefully considered in relation to the local forces and requirements, with statements of costs.

In the United Kingdom the loss of foreshores amounted to 182,000 acres in 33 years—(5510 acres per annum or nearly 9 sq. miles). The same difficulties are recorded there as here in efforts to open channels through harbor bars, for it is said:

"As the sand travel has perplexed harbour authorities their traditional policy has been to push the entrance piers into deeper water as a means of eluding sand travel. Inevitably, as the piers are extended seawards, so the sand has crept out after (or before) them. The sum of the palliative measures may be stated thus: (1) To conserve and concentrate the tidal scour of the ebb tide; (2). To train the sea outfall; (3). To dredge."

This policy has been followed for many years in the United States, and yet the necessity for constant dredging continues and the bars rapidly advance so that jetties of from six to eight miles long, have failed to secure the necessary relief, but in one case at least of a tidal inlet, a portion of one breakwater was constructed across the bar, detached from shore, to admit the *flood tide freely*, which is a *sine qua non*, and it followed there was *no bar advance* and *no dredging was necessary* to secure and maintain the automatic channel thus created.

Much valuable data is recorded as to the plants most effective in restraining the travelling dunes driven by Aeolus and suggestive information as to State and Local jurisdiction which so frequently retards the urgent development of remedial measures. "Amongst these problems none takes precedence to that of national waterways and harbours." They are "the index of commercial progress." These and many other vital questions in physical and political economy are forcefully stated, and render this work of peculiar interest, in the welfare of national economy.

L. M. HAUPT.

TRAITÉ DE MÉCANIQUE RATIONELLE. By Paul Appel. 4th edition, entirely recast. Vol. i. 8vo. viii–602 pages and contents. Paris, Gauthier-Villars et Cie., 1919. 36 francs.

Besides improvements in many details and the addition of new bibliographic information, there has been added in the first chapter a dissertation on the theory of vectors. Three types of vectors are to be noted in practical application; unlocalised, gliding and localised. A distinction is also made between axial and polar vectors.

As an exercise on the movement of a point, there is presented a study of the simplest cases of movement of an electrifid particle, subjected to the action of superposed electric and magnetic fields, This study leads up to some interesting mathematical researches by Poincaré and Störmez, determined by the experiments of Birkeland and Villard and views expressed on the origin of polar auroras put forth by Birkeland and Arrhénius.

L.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS, Report No. 28. An Introduction to the Study of the Laws of Air Resistance of Aerofoils. Preprint from the Fourth Annual Report. 75 pages, illustrations, quarto. Washington, Government Printing Office, 1920. Copies may be obtained free from the Committee.

This report has been written for the purpose of giving a general survey of the present state of knowledge about the laws of air resistance of aerofoils.

A summary of the history of the subject and of the basis of the present-day treatment of the phenomena of fluid resistance is followed by a critical discussion of the fundamental concepts used to describe the fluid resistance properties of aerofoils. Thus are successively examined the concepts of angle of attack, centre of pressure, aerofoil area, metacenter, metacentric curve, zero lift line and resultant air resistance. First is examined the question of the apparent flow deflection produced by an aerofoil, preceded by a preliminary on the general property of vortices; the tip vortices are investigated: a general account on the intensity and direction of these vortices is given. Finally the edge vortices are studied and a general account of their properties is given, including the main qualitative relations that hold for these vortices. The possibility of formation behind an aerofoil of two waves, called the primary and secondary waves, is examined and numerical values of the order of their magnitude are given.

In a set of notes added to the report the following questions are examined: The Kutta theorem, the generalization of the Bernouilli theorem, the equations of the metacentric curves, as well as a translation of the paper of Th. v. Karman and H. Rubach on the Mechanism of Fluid Resistance.

Report No. 35. The strength of One-piece, Solid, Built-up, and Laminated Wood Airplane Wing Beams. Preprint from the Fourth Annual Report. 12 pages, illustrations, diagrams, quarto. Washington, Government Printing Office, 1919.

The purpose of this report was first, to determine by test the suitability of fir and cypress woods for airplane use, compared with Sitka spruce; second, to determine whether a plane rectangular I-section beam possessed any advantage over the oblique I-section beam, which is used at present, other than the advantage of simplicity in shop operation. The increased demand for Sitka spruce has made it necessary to look elsewhere for satisfactory woods that will meet airplane requirements. This report not only deals with experiments leading to the use of a perfectly satisfactory substitute for spruce, but also with the development of some method of construction which will conserve the present supply by utilizing more of the selected material. The tests included not only solid beams to determine their suitability as substitutes for spruce, but also beams built up of three pieces, or

of laminated construction, and tested to determine their strength in comparison with one-piece construction.

The built-up and laminated constructions eliminate the waste involved in the process of cutting the I-section from solid timber. In such construction it is also possible to use woods in short lengths, and though the cost of manufacturing built-up beams is somewhat greater than that of producing the solid beams, the cost of the raw material utilized is much less than the cost of the carefully selected timber used for solid beams.

Report No. 47. Power Characteristics of Fuels for Aircraft Engines. Preprint from the Fourth Annual Report. 35 pages, diagrams, quarto. Washington, Government Printing Office, 1920.

Early in the war the importance of securing the best possible fuel for aircraft engines led to the testing of twelve different gasolines in an aviation engine in the altitude chamber of the Bureau of Standards dynomometer laboratory. During the tests the engine was operated under conditions simulating those encountered in flight at altitudes up to 30,000 feet.

The results of this work, given in this Report, indicate no differences in excess of 5 per cent. in the maximum power developed by each gasoline when the carburetion was adjusted to each fuel. The question of economy is not considered in the report. Several physical properties of the fuels, including the distillation temperatures, were compared in an effort to identify those controlling the power producing ability, but no correlation was disclosed. R.

PUBLICATIONS RECEIVED.

Accounts Rendered of Work Done and Things Seen, by J. Y. Buchanan, M.A., F.R.S. 435 pages, illustrations, plates, tables, maps, 8vo. Cambridge, University Press; New York, G. P. Putnam's Sons, 1919. Price, $6.75.

Selling Your Services, by George Conover Pearson. 237 pages, 12mo. New York, Jordan-Goodwin Corporation. 1920.

Rätsel der Natur und Totengräber der Wahrheit, von Johannes Zacharias. 120 pages, illustrations, plates, portrait, 8vo. München, Johann Goebel, 1920. Price, 6 marks 16 pfennig.

Ontario Bureau of Mines: Twenty-eight annual report, 1919, Part I, 254 pages, illustrations, plates, maps, 8vo. Toronto, King's Printer, 1919.

U. S. Tariff Commission: Tariff Information Series No. 13. The Acids of Paragraph 1 and Related Materials Provided for in the Tariff Act of 1913. 85 pages, 8vo. Washington, Government Printing Office, 1920.

Canada Department of Mines, Mines Branch: Bulletin No. 27. Results of Forty-one Steaming Tests Conducted at the Fuel Testing Station, Ottawa, by John Blizard, B.Sc., and E. S. Malloch, B.Sc. 83 pages, diagrams, 8vo. Production of Iron and Steel in Canada During the Calendar Year 1918. 36 pages, 8vo. Ottawa, King's Printer, 1920.

U. S. Bureau of Mines: Technical Paper 232. Petroleum Technology 53. Absorption as Applied to Recovery of Gasoline Left in Residual Gas from Compression Plants, by W. P. Dykema and Roy O. Neal. 43 pages, illustrations, plates, diagrams, 8vo. Technical Paper 240. Boiler and Furnace Testing, prepared by Rufus T. Strohm. 23 pages, illustrations, 8vo. Washington, Government Printing Office, 1920.

CURRENT TOPICS.

Forest Products Laboratory, U. S. Department of Agriculture, Technical Notes.—This laboratory, at Madison, Wis., is engaged in the study of the properties and economic uses of woods. It has been giving especial attention lately to the application of wood in the construction of airplanes and as a source of paper.

Resistance of Airplane Parts to Decay.—This has now become of much practical importance. During the war, when the operation of a plane was liable to many interferences, the durability of the wood was of minor moment, but instances are now coming to notice in which replacements are needed in otherwise good conditioned planes, owing to decay. It appears that many woods are unsuitable for such use on account of lack of durability, but fortunately other woods of good quality are available. The best of these so far known is Port Orford cedar, after which come southern cypress and California redwood. Douglass fir, white oak and black walnut are fairly satisfactory. It is claimed that mahogany and Spanish cedar are also durable, but these have not yet been tested. Spruce which has been used so much in the United States is inferior in durability, and basswood, beech, birch and maple must also be classed with the inferior kinds. In all cases heartwood should be used. Preservative treatments may enable a somewhat less durable wood to be used if the better kinds are not available. Sodium fluoride may be used on parts that are to be glued, and so-called coal-tar creosote for parts not to be glued. Decay in struts, propellers and some other large members can be prevented by applying aluminum leaf.

Pulp Yield Reduced by Long Storage.—Comparative tests showed that while green wood yielded three and one-half tons per digester, the same wood after a year's storage yielded only three tons, and after two to three years the yield was only two and one-half tons. These losses are not compensated by any reduction in operative expenses, which indicates that the woodyard should be operated so that the material is used as nearly in rotation as possible.

Length of Wood Fibres.—The common opinion that each species of wood has a characteristic fibre-length is not borne out by the extended tests carried out by the Forest Products Laboratory. These measurements show that a greater difference may be found in the fibres from a given tree than between the average length in different species. No clearly defined relation has been found between the length of the fibre and the strength of the wood. The longer fibres are often found in the weakest material.

Resistance of Greenheart Timber to Marine Borers.—Six years

ago the laboratory placed specimens of this kind of timber in the Gulf of Mexico at points at which the water was much infested with several types of marine borers. A recent examination showed that with the exception of a slight trace of limnoria on the sapwood of one specimen, they were uninjured by either limnoria or xylotrya. All, however, had been severely attacked by pholas, which had made burrows from three-quarters to one and a half inches deep. It is not expected that the burrows will be materially deeper, as pholas does not make deep burrows, but the experiments show that if greenheart wood is used in such waters, the piles should be made large enough to allow for reduction in size by such attacks.

H. L.

Liquid Purification of Gases. (*The Gas Age* for February 25, 1920, vol. xlv, p. 161.)—LESTER M. GOLDSMITH describes an apparatus for removing sulphur from gases by using lime or ferric oxide in suspension in water, instead of the dry purifier, which has been so long a feature of the gas-producing plant. The latter has several objectionable features, among which are large area occupied, spare purifiers required for alternation, labor for renewing the beds and fire hazard. The water scrubber and cooler has never been developed seriously as a purifier, being only used as a secondary item. The Atlantic Refining Company after studying thoroughly all existing types of purifiers, decided that the dry purifier is unsuited for the treatment of large volumes of gas containing from 500 to 15,000 grains of sulphur per 100 cubic feet. It was decided to build an experimental plant of such form that it would be automatic, or nearly so, in operation, and involve a minimum outlay for space and labor. A suggested form of such a purifier was presented by H. Hodgson, of the United Gas Improvement Company. It consisted of two contact towers, one of wood and the other of steel, both with wood grids, the arrangement being such that the gas was passed in counter current to the liquid containing the purifying oxide in suspension, the liquid being subsequently pumped to a wooden tower in which it encountered a current of air to bring about revivification. Experiment showed that checker brick was superior to wooden grids for surface of contact, and therefore both towers were subsequently constructed of steel, filled with spiral brick checkered in symmetrical layers.

Numerous experiments were conducted and it was found that a suspension containing 3 per cent. of the iron oxide was most satisfactory. Trials with lime showed that this is more costly than iron oxide and the efficiency less. The paper is liberally illustrated by drawings of the installation and diagrams of its performance. Analysis of a sample of the iron oxide as delivered showed the presence of over 5 per cent. of combined sulphur and

about 3 per cent. of free sulphur. A sample of the exhausted oxide showed as follows in per cent. of total residue:

	Primary tower	Secondary tower
Free sulphur	88.9	39.3
Combined sulphur	0.52	1.74
Ferric oxide	6.79	30.76

The general conclusions from the experiments are:

1. In given apparatus under the same conditions there will remain a constant percentage of sulphur in the purified gas, whether the crude gas contained 10,000 grains per cubic foot or 1000 grains per cubic foot, and it is believed that this same relation will hold good with gases of lower sulphur content.

2. In any liquid purification plant built with two similar towers, passing the gas through in series, it can be expected that the first tower will remove 93 per cent. of the sulphur when the total purification is 95 per cent.; showing that the greater difficulty is encountered in removing the last traces of sulphur.

3. If the purifying liquid is maintained at a temperature between 90° and 100° F., the candle-power loss will be held down to a negligible quantity.

H. L.

Paint Manufacturers' Association of the United States has recently issued the following circulars through its Educational Bureau:

81. *Tuna Fish Oil.*—The gravity, iodine number, and saponification value of this oil were similar to the constants shown by linseed oil. The high iodine value (184) is of great interest, as it is really higher than that of most samples of linseed oil. Comparative drying tests proved that tuna oil dries even more rapidly than most grades of raw linseed oil. The excellent results obtained with this product indicate that the paint industry can utilize all that can be produced.

82. *Metre Equivalents.*—In this circular the value of the metric system is pointed out for use in export trade. Comparative information is given regarding the contents of the United States liquid gallon, the British imperial gallon, and the metric measures of like capacity. All the equivalents in metric and United States units of measure are given, including length, mass and capacity.

83. *Hexabromide Tests for Determining the Purity of Soya Bean Oil and Linseed Oil.*—Two methods are given for determining the hexabromide value of linseed oil. Since linseed oil has a hexabromide value of approximately 44, whereas soya bean oil has a value of only 5, it is possible by this novel method to detect soya bean oil in linseed oil, heretofore impossible by any other analytical method.

84. *Standards for Tung Oil.*—The method recommended is a modified form of the Browne method, and an illustration appears of the apparatus that is used. It is probable that this method gives more concordant results than any other existing method. The circular also discusses the Agnew open-pan heat test method for determining the purity of tung oil.

85. *Oil Absorption of Pigments.*—This circular is probably one of the most important issued by the Educational Bureau during the year. It presents a method of determining the oil absorption value of different pigments and points out the difference between absorption and adsorption. It presents data showing the oil absorption value of several different pigments in different types of liquids. A full description of the apparatus required, method of procedure, etc., for running the tests, is given.

86. *Yellow Tail Fish Oil.*—The results of an examination of yellow tail fish oil obtained on the west coast through the Bureau of Fisheries are presented. The constants are similar to those given by linseed oil. In the comparative drying tests described yellow tail fish oil gave results almost as satisfactory as linseed oil.

87. *A New Method of Determining the Acid Value of Varnished and Boiled Oils.*—A method is presented for determining the real acid value of varnishes, boiled and bodied oils. The old method of using alcohol gives erroneous results where the liquids to be examined are colloidal. It is further shown that through the use of a mixture of alcohol and benzene the colloidal condition is broken down and true solution of the acids brought about, so that accurate results may be obtained.

H. L.

Forest Products Laboratory Technical Notes, Madison, Wis.

Tearing Strength of Paper.—There is no relation between the actual toughness of paper and the values obtained by the commonly used testing machines. Employing a Schopper tensile machine it was found that the toughness can be numerically rated, but that the breaking length, percentage stretch and number of folds give very little information about this property. Figures are given for results on different types of commercial paper, showing the correctness of the general statement above made. (Circular 97.)

Fuel Value of Wood.—Two pounds of dry wood of any non-resinous species have about the same heating value as a pound of good coal. A ton of coal may be taken as equivalent to one cord of heavy wood, one and a half cords of medium weight, or two cords of light wood. Resin gives twice as much heat as wood, weight for weight, hence pines firs have a much higher heating power than the non-resinous forms. The resin content is considered to be about 15 per cent. The fuel value of wood,

however, depends upon several other properties than the calories, such as easy ignition, rapid burning, and smokeless and uniform heat. As a rule, soft wood burns more readily than hard and light more readily than heavy. Pines give quick, hot fires, but oak gives a steady heat. (Circular 98.) H. L.

An Absorbent for Carbon Monoxide. (*Jour. Ind. and Eng. Chem.*, 1920, v. 12.)—Hopcalite is a new compound for removing the carbon monoxide, a deadly gas, from the air in places where workmen are exposed to its effects.

Carbon monoxide is the poisonous constituent of illuminating gas and is responsible for the deaths of persons who inhale the fumes from gas jets. The use of an adequate filter in gas masks would be of great value to firemen and others entering a room in which there is free illuminating gas. The carbon monoxide also appears in the fumes from automobiles which sometimes overcome workmen in repair shops and garages.

Hopcalite was devised originally for use as a filter in the army gas masks, and the experiments which led to its development were kept under the seal of military secrecy. An account of them is now published for the first time in the current number of the *Journal of Industrial and Engineering Chemistry* of the American Chemical Society, as a contribution from the Chemical Warfare Service. The publication is authorized by the Director of the United States Bureau of Mines and by the Director of the Chemical Warfare Service. The authors of the paper are Arthur B. Lamb, William C. Bray and J. C. W. Frazer.

Carbon monoxide is so harmful that at one time it was considered as a poison gas for use in war. Although it was found to be unavailable for intentional use, it was a factor none the less in a military sense, when it gathered in confined spaces.

"In one of the naval engagements between the Germans and the English," to quote from the paper, "defective high explosive shells, after penetrating into inclosed portions of ships, evolved large quantities of carbon monoxide and thus killed some hundreds of men. On shore, machine gun fire in inclosed places such as pill boxes and tanks liberates relatively large portions of carbon monoxide and has been responsible for numerous casualties. Similarly in mining and sapping work, the carbon monoxide liberated from the detonation of high explosives constitutes one of the most serious of the difficulties connected with this work, and has necessitated elaborate equipment and extensive military training in mines rescue work.

"Carbon monoxide is also a serious hazard in peace as well as in war. In the manufacture of power and illuminating gas, and in the metal industries where this gas is largely employed, casualties and indeed fatalities are constantly occurring. In coal mining, in certain classes of copper mining and wherever explosives are used

in confined spaces, carbon monoxide is a serious menace responsible for the loss of many lives each year. Leaky flues, exhaust gases from explosive engines, improper ventilation where coal fires are employed and the air to which firemen are exposed to burning buildings all constantly take a not inconsiderable toll of human lives."

So important is the fight against carbon monoxide regarded in the future, that special investigations have been begun lately to determine the best means of combating it in spaces where automobiles are moving under conditions where there is little ventilation. Thirteen students of Yale University recently volunteered to submit themselves to tests, to determine how much of the gas the human system could tolerate when mixed with air. The proposed experiment was suggested by the plans for the huge vehicular tunnel under the Hudson River which is to connect New York City and New Jersey. Through it will be moved many automobiles and power trucks at different levels, and the carbon monoxide factor is considered a strong one in planning systems of ventilation for the colossal bore.

The research which resulted in the development of hopcalite began at the University of California. The group of investigators were transferred to a station at the American University, at Washington, D. C., and Washington and Baltimore laboratories worked in collaboration. The Hopcalite first made consisted of a mixture of fifty per cent. manganese dioxide, thirty per cent. of copper oxide, fifteen per cent. of cobalt dioxide and five per cent. of silver oxide. Minor modifications have since been made in the process.

It was ascertained that this mixture placed in an ordinary gas mask canister worked very well. Its usefulness, however, is gradually impaired by the absorption of moisture. This danger point can readily be determined by weighing the canister from time to time and discarding the mixture when its weight reaches a certain weight.

Recent Investigations on Milk and Butter.—G. C. SUPPLEE, in a thesis published by the *Cornell University Experiment Station*, presents the results of studies to determine the lecithin content of butter and its relation to the fishy flavor occasionally observed which reduces its commercial value, although it may have no sanitary significance. After a discussion of the literature, the author sets forth data derived from a careful study of the lecithin content of many samples of butter, as there appear to be no reports on this question. It was found that lecithin in appreciable quantities could be obtained and identified by appropriate tests. Quantitative determinations were made on butter made from cream respectively raw and ripe, pasteurized and sweet. In all these notable amounts of lecithin were found. Ripened cream seems to yield a butter with a less lecithin content than the raw cream. Confirmative reaction was obtained by the production of choline periodide, the crystals of which are distinct and of which photmicrographs are

shown. The final conclusion of the investigation is that the fishy odor is due to small quantities of trimethylamine produced by the decomposition of the lecithin. A definite acid condition is essential to the development of the fishy flavor, and is most likely to be produced when butter is made from cream containing lactic acid, whether this latter is produced by fermentation or by direct addition, but some strictly biologic condition must also exist.

H. L.

The Food Value of Milk is discussed at length and from the results of many experiments by Edna L. Ferry in Bull. 215, Dec., 1919, of the Connecticut Agric. Exper. Sta. The following are the principal points established:

Milk is absolutely essential for the young, is a desirable addition to the diet of adults, and the main reliance in many cases of disease. Milk is especially adapted to supplement the protein deficiencies of the cereals which constitute so large a part of human food, in addition to which its content of the three so-called "vitamins," makes it almost indispensable for "growing" animals, but it is not yet proved that they are all essential to maintaining health in well-developed adults. One of the vitamins—known provisionally as the scurvy-preventing form—is destroyed by heat, and therefore, it is to be inferred that for infants fed on pasteurized or sterilized milk, some other food, such as orange juice, containing this vitamin should be liberally used. The investigator declares that milk at 16 cents a quart is a cheaper food than beef at 35 cents a pound or eggs at 35 cents a dozen. H. L.

Liquid Oxygen and its Application as an Explosive in Mining. R. PAPST. (*Zeit. Ver. Deutscher Ing.*, Jan. 3, 1920.)—According to this book review the use of liquid oxygen as an explosive acquired considerable vogue in Germany during the war. Indeed the members of The Franklin Institute saw pictures of certain phases of its use in the thoughtful destruction of French industrial plants upon the occasion of the lecture of Mr. George S. Rice on November 19, 1919.

Since 1914 the "Sprengluftgesellschaft" has made great progress in the handling of liquid air. The kernel of the matter lies in the production of special vacuum vessels in which the liquid can be shipped and in which it will remain at −180° C.

It is possible to produce on a wholesale scale cartridges of long life and of a wide range of explosive properties. The difficulty of having the fuse at the very low temperature of the liquid air has been overcome. A great advantage of this type of explosive is its harmless character so long as the cartridge and the liquid air are not in intimate contact.

The suggestion is made that land can be cleared of stumps at a cost of about 4 marks per square meter. G. F. S.

The Recent Eclipse Results and Stokes-Planck's Aether. L. SILBERSTEIN, Univ. of Rome. (*Phil. Mag.*, Feb., 1920.)—In 1845 Sir G. G. Stokes proposed a theory of aberration in which the ether at the earth's surface was supposed to be dragged along with the earth and at the same velocity. The dragging effect grew less as the distance from the earth increased, until it ceased entirely and the ether had no motion imparted to it by reason of the earth's motion. Later Planck added the important detail that the ether is condensed near bodies such as the earth which have the force of gravitation.

Prof. Silberstein believes that this theory accounts for the aberration of light, "for the older terrestrial optical nil-effects," "also for the nil-effect of the Michelson-Morley experiment." "The bending of rays of light round the more massive terrestrial bodies would be only a by-product of the theory." This rival to the Einstein theory thus accounts for the bending of the rays of light from stars when the path is close to the sun as was observed to be the case at the solar eclipse of 1919. It does not, however, carry with it as a consequence that there should be a shift in the lines of the spectrum as does the Einstein theory. This shift is "obstinately absent," yet, on the other hand, in *Nature*, Jan. 29, 1920, is cited a passage from a letter coming from Einstein in which he says that two young physicians in Bonn have as good as proved the existence of the displacement effect in the spectrum lines.

G. F. S.

Glues Used in Airplane Parts. (*Report 66, National Advisory Committee for Aeronautics.*)—This report compiled by S. W. Allen and T. R. Truax, of the Forest Products Laboratory, U. S. Dep't Agriculture, gives a large amount of information on the composition and efficiency of the many forms of glue that have been tried out with the airplanes. Brief accounts are given of the glues, and a classification of them, a classification that is somewhat arbitrary, probably for strictly practical reasons, as a distinction is made between "animal" glues and "liquid" glues, although both kinds are prepared from animal tissues. Vegetable glues are generally made from starch, the cassava being the usual source. Casein glues contain casein mixed with lime and other ingredients. Blood-albumin glues are usually sold in powdered form and when dissolved must be used promptly, being very liable to decomposition. Descriptions are given of the standard methods of manufacturing of all these forms of glues, the precautions to be taken in applying them, and a bibliography of each type. In comparing the efficiency of the different types, ordinary animal glue, on account of its long use and familiarity to all wood-workers, is taken as the standard. This form has some very desirable properties, among which are great strength and reliability in the higher grades, free flowing and the fact that it does not cause staining in fancy veneers. So far no

substitute has been found for this glue for hand-spreading on irregular joints. The price of the article and the fact that it is not water-resistant are the chief factors that limit its use. Casein glue has high water-resistance, is easily spread, strong and can be used cold, but it stains veneers, and some forms have short working life. Vegetable glues have found extensive use in recent years on account of their cheapness. They also may be used cold and remain in good working conditions for many days, but are very viscous, cannot be spread by hand, are not water-resistant and usually cause staining in thin veneers. Blood-albumin glue has notably high resistance to moisture, especially in the boiling test, which makes it useful in cementing plywood that is afterwards to be softened in hot water and molded. It is possible to make very cheap glues of this type. The drawbacks to blood-albumin glue are the expensive apparatus required, the relatively low production and the fact that it is not very suitable for gluing thick stock.

Liquid glues are in general similar to the standard animal glue, but the commercial forms are not uniform, some being quite strong and others weak. Their great advantage is that they come ready for use, which makes them suitable for patch-work and small jobs. The high price, low water-resistance and difficulty in distinguishing between good and bad brands are serious drawbacks. Several pages are devoted to summarizing the testing methods and results.

H. L.

The Mechanism of the Addition of Hydrogen to Unsaturated Glycerides in the Presence of Finely-Divided Nickel has been studied by R. THOMAS (*Journal of the Society of Chemical Industry,* 1920, xxxix, Transactions, pp. 10–18). The more highly unsaturated glyceride linolin added hydrogen at a very considerably greater rate than did the less unsaturated glyceride olein. The hydrogen apparently becomes active by absorption in the nickel, which plays the part of a catalyst, and is dissociated from molecules into atoms. The olein is brought into an active condition by infrared rays emitted by the catalyst; and the reaction is photochemical in nature. Gaseous catalyst poisons may act in a purely physical manner, or may act in a chemical manner, either reacting in the presence of the catalyst *e.g.* carbon monoxide, or combining with the catalyst, *e.g.* hydrogen sulphide. J. S. H.

Industrial Research.—In a bulletin of ARTHUR D. LITTLE, INC. (Bibliographic Series No. 3), entitled "A Reading List on Industrial Research," by West and Greenman, Dr. Little writes an introduction in which he says among other statements: "Within a professional experience of more than thirty years nothing has been so striking as the sudden recognition of the fundamental importance of research, by governments, leaders of industry, and the man in the street, during the progress of the war. The war itself has been

characterized as a chemist's war, and chemistry has permeated every aspect of it. The chemists of all the belligerent countries have been organized into the equivalent of what we have termed the Chemical Warfare Service, and for the time, to which we may now happily refer in the past tense, the entire chemical brain and energy of each combatant nation was engaged in the solution of problems of offense and defense." A single producer found it necessary to employ a thousand chemists. "Thus," adds Dr. Little, "it has become the duty and the privilege of those of us who are familiar with this method and its application to preach the Gospel of Research."

H. L.

Digestibility of Certain Miscellaneous Vegetable Fats.—ARTHUR D. HOLMES and HARRY J. DENEL, JR., have found that the digestibility cœfficient of fats, which have melting points above body temperature, varies inversely with the melting point. The tolerence of a fat by the human body governs its use in the dietary. In the present paper (*Journal of Biological Chemistry,* 1920, XLI, 227–235), these investigators have studied the digestibility of certain less commonly used fats, which may be of value in times of shortage of the more common fats. The fat of the avocado fruit is 87.9 per cent. digestible. Cohune oil, derived from the kernel of the cohune palm, *Attalea cohune,* of Central America, is 99.1 per cent. digestible. Cupuassú fat, which is expressed from the seeds of the cupuassú tree of Brazil, is 94.1 per cent. digestible. Hemp seed oil is 98.5 per cent. digestible. Palm kernel oil is pressed from the interior portion of the kernels of the fruit of the African palm tree, *Elaesis guineensis;* it is 98.0 per cent. digestible. Poppy seed oil, which is produced in the Orient and is used as an edible oil in Europe, is 96.3 per cent. digestible. These oils and fats exerted no unusual effect on the utilization of the protein and the carbohydrate in the diet; none of them produced any abnormal physiological effect except cupuassú fat, which caused slight disturbances.

J. S. H.

Industrial Uses for the Shark and Porpoise are enumerated by Dr. ALLEN ROGERS, in the *Journal of the Society of Chemical Industry,* 1920, xxxix, Transactions, pp. 9–10. The sharks are caught in nets. The fins are removed, dried in the sun, and sold to Chinese as an ingredient for soups. The skins are removed, fleshed by machines, pickled in salt and sulphuric acid, and finally submitted to tanning processes to obtain either bag leather or shoe leather. The flesh and bones are ground, then dried in a rotary dryer to obtain a fish scrap fertilizer which contains from 15 to 17 per cent. of nitrogen calculated as ammonia. The livers are allowed to disintegrate for several days, then are heated to boiling for approximately one hour in steam-jacketed kettles to remove the oil, which

is purified by washing and settling. Porpoises are caught and utilized in a similar fashion; however, the blubber and the jaw oil are collected and used separately for the manufacture of oils. The flesh of both sharks and porpoises is edible, and should serve as a source of food for man.

J. S. H.

Army Ration.—DR. MERKEL H. JACOBS, Captain, Sanitary Corps, United States Army, has studied the army ration and its balance (*Military Surgeon,* 1919, xliv, 600–616). Under ordinary conditions, a soldier eats sufficient food to obtain, on the average, from 3200 to 4000 calories daily. In a permanent camp his average daily food consumption is 3600 calories, including 1200 calories at breakfast, 1300 calories at dinner, and 1100 calories at supper; 110 grams of protein or nitrogenous food and 97 grams of fat are eaten daily; the remainder of the energy is supplied by starches and sugars in the foodstuffs. A deviation of 200 or 300 calories from the average is permissible on some days provided the general average be maintained.

J. S. H.

Carotinoids as Fat-Soluble Vitamine.—The provisional assumption has been made that the fat-soluble vitamine is identical with one of the carotinoids or pigments of the fats. PALMER (*Science,* 1919, l, 501–502) points out that the fat-soluble vitamine may occur in nature in the absence of carotinoids, and that carotinoids may occur in nature and the absence of the fat-soluble vitamine. Thus, fresh cotton-seed oil contains carotinoids but no fat-soluble vitamine; the milk fat of certain animals contains fat-soluble vitamine but no carotinoid. Therefore the fat-soluble vitamine cannot be identical with a carotinoid pigment.

J. S. H.

Longevity of Bacteria in Bottled Commercial Spring Water.—MAUD MASON, Obst. (*Journal of the American Pharmaceutical Association,* 1919, viii, 735–745), concludes that water can be stored in bottles so that contamination will not enter. When a stored bottled water is re-examined within a period of 30 days, the two analyses may or may not yield the same bacterial count; but *B. coli,* whose presence indicates fecal pollution, will probably not increase during the interval between the analyses. Even after storage for 3 years, pollution can be detected in a bottled water; such water may not be used with safety for drinking purposes. Apparently certain salts favor, and other salts are antagonistic to, the longevity of bacteria in commercial waters. The presence of moulds in large numbers in a bottled water suggests storage. In the presence of water bacteria, *B. coli* may live in bottled spring waters for several years; it is not safe to assert that *B. typhosus*

(the organism of typhoid fever) and other members of this group of bacteria will not survive long periods of storage under similar conditions. When pure cultures of *B. coli.*, *B. typhosus,* and *B. dysenteriæ* (the organism of bacillary dysentery) were introduced into sterilized, bottle spring waters, these organisms did not multiply; in fact they underwent a steady decrease in number. However, *B. dysenteriæ* was recovered alive from 3 such waters 4 or 5 days after inoculation; and *B. typhosus* was recovered alive from a water which had been stored for 2 months after inoculation.

J. S. H.

Specific Heat of Liquid Hydrogen and of Solid Hydrogen. Heat of Fusion of Hydrogen. W. H. KEESOM and H. KAMERLINGH ONNES. (*Communications from the Physical Laboratory of the University of Leiden.*)—Liquid Hydrogen. The calorimeter was jacketed with solid hydrogen. Heat was applied to the liquid, whose temperature ranged from 15 to 20 degrees absolute, by means of an electric current. The values of the specific heat varied from 1.67 to 2.18 calories per gram.

Solid Hydrogen. The results are merely preliminary. The values of the specific range from .45 to .73. Thus the product of the specific heat of hydrogen by its atomic weight (atomic heat) is only a small part of the value which other solid elements have for this quantity. It is noticed that hydrogen like water has a smaller specific heat in the solid than in the liquid phase.

Heat of Fusion. A mean value of 15 calories per gram is given as the result.

G. F. S.

Annual Physical Society and Optical Society Exhibition. London. (*Electrician,* Jan. 16, 1920.)—The last previous exhibit of the Physical Society was held in 1913. The Admiralty and the Air Ministry displayed instruments captured from the Germans, mostly of an optical character and of surprisingly crude workmanship.

One especially interesting exhibit was an electrical CO_2 recorder to measure the percentage of this gas in flue gases. Two exactly similar spirals of platinum wire are supported in similar holes in a copper block and are made two arms of a Wheatstone Bridge, which is then balanced so that the galvanometer shows no deflection. While the same current flows through both spirals, they lose heat equally and remain at the same temperature, provided they are surrounded with the same gas. If one, however, is surrounded by air while the other has flue gas around it, the heat loss will be different and by consequence the temperatures of the spirals and the electrical resistances will differ. This destroys the balance of the bridge and the galvanometer deflects. From the amount of the deflection the percentage of CO_2 is inferred, in fact the galvanometer records directly upon a chart from which percentages can at once be read.

G. F. S.

American Pulp-Woods.—The Forest Products Laboratory of the U. S. Dep't of Agriculture has reprinted as a bulletin a collection of data (originally appearing in *Paper,* July 30, 1919) concerning the American woods that may be available as sources of paper-pulp. The great demand for paper has brought about investigations for new sources. The experiments were made in semi-commercial digestors carrying about 100 pounds of material. It was found that the general cooking conditions, yield, bleach consumption and other points as derived from the experimental plant compare satisfactorily with results obtained on the large scale. The publication gives detailed information as to the suitability of about two score American trees, mostly in relation to the sulphate, sulphite and mechanical processes, but a few also for soda-pulp. With each tree is given the approximate distribution, the scientific and common names, the yield under the different methods, the physical qualities of the pulp and the most likely use that can be made of it in the paper trade. There is a great range of applicability noted. The experiments have been going on for ten years.

H. L.

Production of Alcohol from Sulphite Liquors. (*Bibliographic series No. 2,* ARTHUR D. LITTLE, INC.)—This is a bibliography of a little over one hundred items on the literature of the manufacture of alcohol, principally ethyl from the waste liquor of sulphite pulp works. This highly objectionable waste has been the subject of extensive studies with a view to find some use for it that will make its utilization reasonably profitable. The list was prepared by Clarence D. West. The items are arranged by authors alphabetically. It might be a better plan to arrange them chronologically. The extent of the bibliography shows the interest that attaches to this subject.

H. L.

Effect of Light on Glue. (*Aircraft Technical Note, Bureau of Construction and Repair, Navy Department.*)—LIEUT. GARDNER, U.S.N.R.F., reports that inquiries having been made as to the possible effect of ultra-violet light on glue used in laminated wood construction, investigations have been started, though the impression is that the effect will be slight. The basis of the inquiry is probably the general opinion that the intensity of the ultra-violet light increases with altitude, owing to the less absorption by the atmosphere. It is noted that the older method of finishing plywood with varnish would not protect the glue, but the department now uses a gray enamel which is practically opaque to light rays.

Veneer Tests.—In the bulletin above quoted, the experiments of the Forest Products Laboratory with several types of glues used in fastening veneers are recorded. Panels suitably prepared were

exposed to the action of fresh and salt water, gasoline and engine oil, boiling and soaking and to differing conditions of atmospheric humidity. Fresh and salt water seemed to have about equal effect. Glued panels that resist eight hours' boiling, followed by subsequent drying, will also stand twenty-four hours' baking. For inspection purposes the boiling has been limited to eight hours, which is equivalent to a ten days' soaking test. Panels that pass this test will stand much exposure to atmospheric humidity.

H. L.

Prevention of Dope Poisoning. (*Aircraft Technical Note, Bureau of Construction and Repair, Navy Department.*)—Workmen who apply the dopes to wing fabrics find often serious skin troubles on the hands. It has been found possible to eliminate much of this difficulty by using vaseline, glycerol or similar emollients rubbed well on the hands before beginning work. The dried dope does not then adhere firmly to the skin and can be removed by rubbing in a further portion of the emollient and washing with soap and water. An application of vaseline to the cleaned surface is beneficial. Dopes containing tetrachlorethane, which is volatile, cause pronounced jaundice to those much exposed to the vapors of it, and this solvent is, therefore, not approved by the Navy Department. The solvents now used are not strongly toxic, but in all such work active ventilation should be maintained.

H. L.

Royal Belgian Academy, Section of Sciences. (*Bull. Classe des Sciences,* 1919, p. 158.)—Formally decided to sever relations and to cease the exchange of publications with the learned societies of Germany, Austria, Hungary, Bulgaria and Turkey, to send no publications to the savants of these nations, to refuse to receive and to return such publications as should be sent to the Academy by authors or societies in the five enemy countries and to employ the usual channels of commerce to purchase such publications as seem strictly essential.

G. F. S.

Thermostat for Low Temperatures. P. BRUYLANTS and W. MUND. (*Bull. Classe. des Sciences. Acad. Roy. de Belgique,* 1919, p. 113.)—The boiling of a pure liquid under a constant pressure furnishes a fixed temperature and is especially applicable when rather high temperatures are desired. The melting of pure solids in contact with their liquids gives another method, but the presence of a small quantity of impurity makes quite a difference in the melting point. The authors employ the constancy of temperature at which cryohydrates solidify. Cryohydrates are solutions of salts in water of such strength that they are saturated at the temperature at which solidification occurs. The resulting solid therefore is composed of both solvent and solute and the unfrozen part of the liquid remains

saturated as at the beginning of freezing. A table of cryohydrates is given whose temperatures of solidification range from −62° to −2.9° C. For instance, 42.5 gr. calcium chloride in 100 gr. water solidifies at −55°.

A large Dewar bulb, filled with alcohol or ether, contained a cylindrical vessel enclosing the cryohydrate (eutectic). The constancy of temperature was such that in one case the change in an hour and a half amounted to only .03°, while the largest change was .07° in four or five minutes.

A disadvantage is the likelihood of the solidification of the cryohydrate causing the breaking of vessels immersed in it.

The article bears the date July, 1914, Louvain—a month before the town fell into the hands of the Germans.

G. F. S.

The Measurement of Magnetic Susceptibilities of Low Order. ERNEST WILSON. (*Proc. Royal Soc.*, A680 Feb., 1920.)—In connection with the new magnetic survey of the British Isles it was found desirable to have a convenient instrument for the measurement of low magnetic susceptibilities such as those of granite and other rocks. The principle of the Curie balance was employed, that is, the specimen under examination was suspended from a torsion thread so that it rested within the air gap of a ring electro-magnet. When a current flows through the coils of the magnet the specimen is deflected and the angle is determined by a mirror. The susceptibility per unit volume is calculated in a simple manner from this deflection, the number of amperes of current and a constant of the instrument.

The instrument can be used to investigate the magnetic properties of powders and of liquids. It promises to furnish a rapid method for determining the relative amounts of ferrous iron in different specimens of glass. Mica was found to have fifty times as great a susceptibility parallel to the laminate as perpendicular to them.

G. F. S.

Bituminous Coal Industry. (*U. S. Geological Survery Press Bulletin*, No. 439, February, 1920.)—At the February meeting of the American Institute of Mining and Metallurgical Engineers in New York the afternoon session on Tuesday, February 17, was devoted to a discussion of the bituminous-coal industry. The fluctuations in production and their extent and causes were discussed in a paper by George Otis Smith, Director of the United States Geological Survey, Department of the Interior, and F. G. Tryon, the coal statistician of the Survey. The statistical facts collected by the Survey during the last 30 years were graphically set forth in a dozen diagrams and certain broad conclusions were drawn from these facts.

The "bad load factor" of the soft-coal mines of the country shows itself in the annual, seasonal, and daily fluctuations in coal

production. On the average, during the past 30 years the mines have been idle 93 working days in the year.

The national interest in bettering the load factor of the soft-coal industry is measured by the fact that we have an excess mine capacity of at least 150 million tons and an excess labor force of perhaps 150,000 men. In terms of man-days, universal military training of our young men for three months would cost the nation less than the present enforced idleness in coal mining.

Chromite Production, 1918. (*U. S. Geological Survey Press Bulletin,* No. 438.)—In view of the record-breaking production of chromite in the United States in 1918, reported by the United States Geological Survey, Department of the Interior, it is of interest to note the part it played in the world's output for that year. The approximate output in round numbers for each country is expressed below in metric tons.

WORLD'S PRODUCTION OF CHROMITE IN 1918.

United States	84,000
Canada	20,000
Cuba	9,000
Guatemala	1,200
Brazil	18,000
British South Africa	28,000
Turkey (Asia Minor)	14,000
Greece	10,000
Austria-Hungary	500
Russia	16,000
India	20,000
Australia	800
New Caledonia	26,000
Japan	8,000

Recent Advances in the Utilization of Water Power. E. M. BERGSTROM. (*Electrician,* Feb. 6, 1920.)—"The outstanding features in the development of the utilization of waterpower can be summarized as follows:

1. The exclusive use of two types of turbines only, namely, Francis reaction turbines for low and medium heads, and Pelton impulse wheels for high heads.

2. The extension of the use of Francis turbines under heads approaching 800 feet, and Pelton wheels in single stage up to 5500 feet.

3. The exclusive adoption of balanced wicket-gates for regulation of Francis turbines and the circular nozzle with combined deflector and needle regulation for Pelton wheels.

4. The standardization of turbine runners and increased specific speed permitting the use of single vertical units of large output under low heads.

5. The general increase of output per unit, the maximum output at present being 31,200 B.H.P.

6. The general increase of the over-all efficiency of about 6 to 10 per cent.

7. The exclusive use of oil-pressure governors.

8. The efficient regulation (by means of differential surge-tanks) of turbines using long pipe lines.

9. The employment of large diameter pipe-lines under high heads, resulting in an appreciable reduction of the initial cost of development." G. F. S.

New Wireless Phone Carries 900 Miles. (*Jour. Am. Inst. Elec. Eng.*, Feb., 1920.)—Wireless telephone conversations have been carried on between Ossining, N. Y., and Chicago over a distance of 900 miles with a power of one-third of a kilowatt. The wave length used was 375 metres. Wireless telegraph operators in Ohio, South Carolina, Massachusetts and Chicago while listening for dots and dashes heard a voice instead of what they were expecting. G. F. S.

Aluminum-dust Explosions.—The phenomena of explosion seem to involve some very peculiar actions. With the better known explosives, such as gunpowder, guncotton and the more recently invented benzene derivatives, the effects are not difficult to understand as they are dependent on the productions of large volumes of hot gas, of high critical points. With many other forms of explosive, however, this explanation does not apply. A minute amount of mixture of potassium chlorate and phosphorus will produce a startling rending effect, and a few grains of sulphur triturated with potassium chlorate will often break a thick-walled Wedgewood mortar, although the hand holding the same is not injured. In these cases we can hardly assume the production of any notable amount of gas.

In a recent number of this JOURNAL an abstract was given of a report on starch-dust explosions from the Bureau of Mines, it being stated that the explosion was unexpectedly violent, exceeding greatly those produced by coal dust and flour. In *Technical Paper 152* of the same bureau, Alan Leighton presents interesting data in regard to explosions of aluminum dust. This material now extensively used in the manufacture of a metallic paint, burns quietly when a small heap of it is ignited, but if distributed through a confined air space combustion takes place with violence. One authority (Stockmeier) states that the powder is not ignited by friction, but mixed with potassium chlorate it is readily so ignited. Mixed with air, aluminum powder can be ignited by an electric spark, and it is thought that some explosions have been caused by sparks from electric fans. It has been noticed that when water is thrown in burning aluminum, large volumes of hydrogen are evolved. Leighton found that aluminum dust laid as a train on a soft wood board could be fired by short circuiting

a current through it, and that when water was thrown on the burning mass a violent puff resulted. It was also found that the dust sprinkled in iron at a dull red heat (about 600° C.) melted and stuck to the iron, but did not burn. Evidently the igniting point of aluminum dust is above that of coal dust. Commercial aluminum dust usually has a thin coating of oil, stearin or some similar substance, which serves to prevent oxidation, as the product loses its luster if not so coated.

The dust is so light that it is easily blown about and usually the articles in the workroom are covered with it. All apparatus should be tightly enclosed. If fan-suction is employed to carry off the waste, some form of dust precipitator should be attached a short distance from the grinding machine to minimize the risk of explosion. Explosions of flour dust often begin at the ventilating fans and spread to the rooms in which the dust is being produced. At the factories at which explosions of aluminum dust occurred, the ventilating systems seemed to be designed to keep the air in rapid motion, hence helped to suspend the material. There was no device to collect the dust.

It is well known that aluminum enters into combination with many elements with great heat disengagement. The heat of formation of aluminum oxide is nearly four times that of carbon dioxide. The metal also has a high specific heat, hence the difficulty of igniting it with small flames.

It is evident that the commercial manufacture of the dust involves serious risks, which should be met by scientific construction of the apparatus and proper ventilating systems. Suggestions along these lines are given in Leighton's paper.

H. L.

Cadmium Production in 1919. (*U. S. Geological Survey Press Bulletin,* No. 440, March, 1920.)—The output of metallic cadmium in 1919 was 99,939 pounds, compared to 127,164 pounds in 1918 and 207,408 pounds in 1917, the maximum output in the history of the industry. The production of cadmium sulphide was 31,197 pounds, compared with 51,702 pounds in 1918. The combined value of metallic cadmium and cadmium sulphide in 1919 was about $160,000, compared with $258,518 in 1918 and $376,036 in 1917. These figures computed by C. E. Siebenthal, are made public by the U. S. Geological Survey, Department of the Interior.

Though prices of cadmium were somewhat lower in 1919 than in the three years immediately preceding, the industry closed the year in better condition than in 1918, for the reason that the consumption practically reached the level established in 1916–17, and this with the decreased production operated to reduce stocks.

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THE PHYSICS OF FLIGHT.*

BY

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INTRODUCTION.

THERE have been many publications in the last few years on the application of physics to the design and construction of airplanes and to the theory of their stability, and much progress has been made on these intricate and important questions. But for every one man who designs a successful airplane there are many who must fly it, and the application of physics to the problems of actual flight has been comparatively neglected, so much so, in fact, that many pilots even overlook entirely the value of physics to a flyer. In this they are apparently confirmed by the fact—and it is a fact—that most of our best pilots during the war were ex-cavalry officers and other men whose previous experience had been such as to cultivate almost any form of knowledge but that of physics. Notwithstanding this, an airplane is governed by the laws of physics, and unless these laws can be made to help a pilot there is some important defect in our system of the teaching of physics. The question is whether this defect is in the laws covered in our physics courses, or the methods of using these laws, or both.

* Presented at a joint meeting of the Section of Physics and Chemistry, the Aero Club of Pennsylvania and the Physics Club, held Thursday, January 8, 1920.

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This question was of especial interest to me in learning the art of flying, because I had been teaching physics for some years, and had been much dissatisfied with the conventional methods of teaching and their results, and had often noticed the same apparent futility of the text-book style of physics in sailing a boat, repairing an automobile, and other applications of the laws of physics where arithmetic does not enter. Such cases suggested strongly that the inadequacy of physics as taught was not so much in the laws as in the methods. The purpose of the present article is not to present any new laws of aerodynamics, and no effort will be made to trace each law to its discoverer, but it is rather to show what appears to me, as a pilot and a physics teacher, to be the best way of presenting the subject to men who are going to fly.

WHAT IS THE PHYSICS OF FLIGHT?

To see what sort of physics a flyer does need, let us examine briefly some typical problems arising in actual flying. We can then examine the laws underlying them, put these laws in the most suitable form, and apply them to some of the problems.

First, let us take the problem of how to climb to 10,000 feet, or some other given altitude, in the quickest time. The first requirement is of course full throttle. Then comes the question of how steeply to elevate the nose of the airplane. If the nose is held too level, the machine will make a high speed, but on a nearly level course. If it is held somewhat steeper the course will be steeper, but the speed lower, and if the speed is too much reduced in this way it may more than neutralize the effect of the steeper course. And if the nose is held too steep, the course, as a matter of fact, may even become more level again, as illustrated in Fig. 1. The first question is how to tell what angle of elevation is best, and the second is whether, in practice, to identify this angle by a spirit level, the horizon, the air speed meter, the "feel of the ship," or something else.

A second problem, closely related to the above, is that of climbing out of a small field where there is danger of striking some obstacle, such as a telegraph wire or a row of trees. In such a case it is sometimes impossible to clear the obstacle by climbing at the ordinary best angle of elevation but just possible to do so by "zooming"; that is, by holding the nose level, heading for the obstacle, perhaps ten or twenty feet below the top, and

FIG. 1.

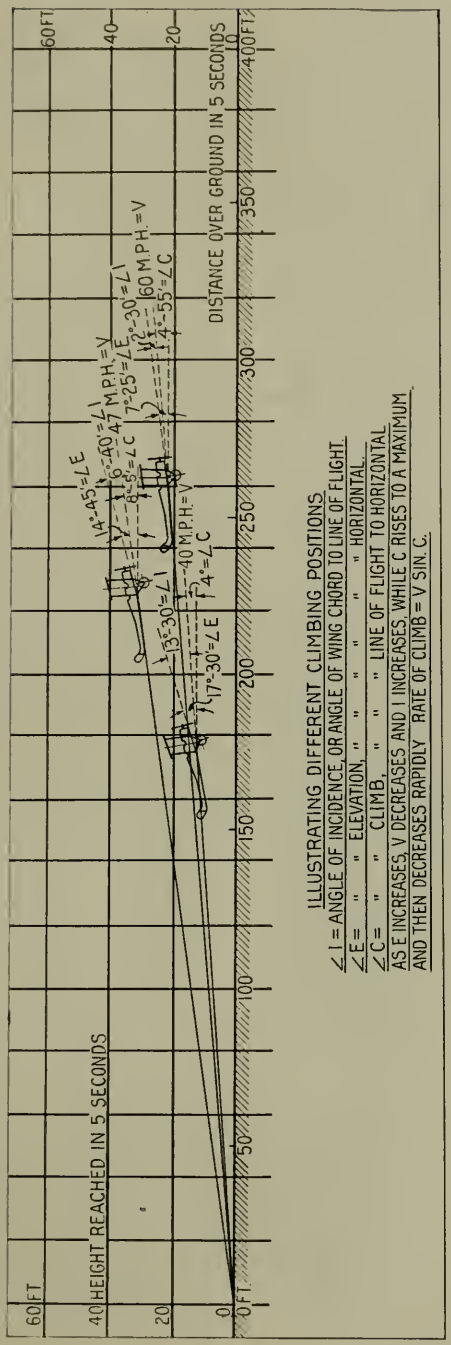
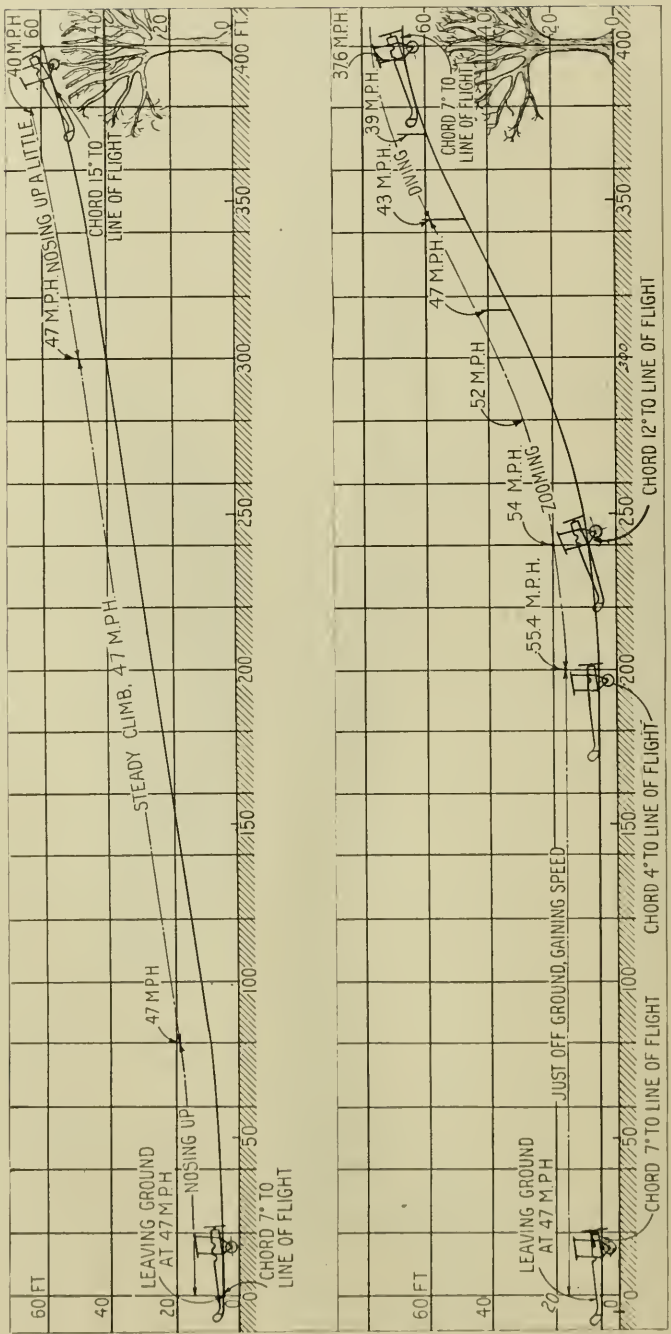

60 FT
40
20
0
HEIGHT REACHED IN 5 SECONDS
0 FT
50
100
150
200
250
300
350
400 FT
DISTANCE OVER GROUND IN 5 SECONDS
10
14°-45'=∠E
6°-40'=∠I
47 M.P.H.=V
8°-5'=∠C
7°-25'=∠E
2°-30'=∠I
60 M.P.H.=V
4°-55'=∠C
13°-30'=∠I
40 M.P.H.=V
4°=∠C
17°-30'=∠E
ILLUSTRATING DIFFERENT CLIMBING POSITIONS
∠I = ANGLE OF INCIDENCE, OR ANGLE OF WING CHORD TO LINE OF FLIGHT.
∠E = " " ELEVATION, " " " " " HORIZONTAL.
∠C = " " CLIMB, " " " LINE OF FLIGHT TO HORIZONTAL
AS E INCREASES, V DECREASES AND I INCREASES, WHILE C RISES TO A MAXIMUM
AND THEN DECREASES RAPIDLY RATE OF CLIMB = V SIN. C.

FIG. 2.



Illustrating a zoom that pays with a ship of fairly high power.

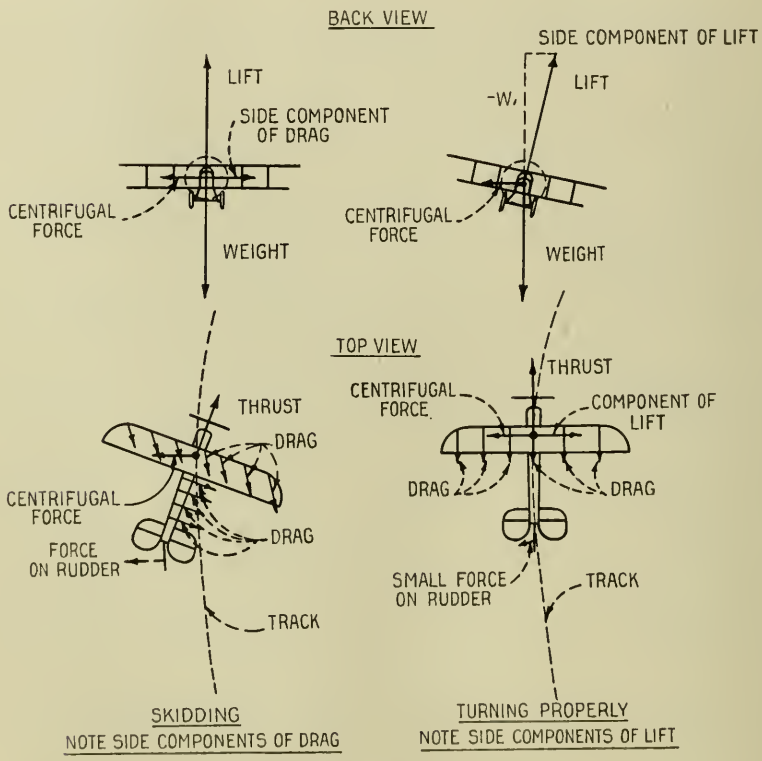
then elevating the nose so as to rise very steeply over the obstacle, then levelling out and perhaps dropping below it on the other side, as indicated in Fig. 2. Several questions arise here, such as: why does this trick work; does it always pay; if it works, why is it not a good way to begin a long climb; is there any danger in it; and why do you fly level in the first part of the process, at a sacrifice of altitude, rather than climb as long as you can and then zoom?

A third problem, also on climbing, arises when you climb out of a field against a strong wind and wish to turn to go before the wind. If you "turn off the wind" within a few hundred feet of the ground, the airplane is often very unsteady laterally during the turn, and sometimes banks up so suddenly as to side-slip toward the ground. This is the cause of many accidents, and such turns should be avoided if possible. An explanation of this effect, accepted by many pilots, is as follows: "If you climb at an air speed of 60 m.p.h. against a wind of 15, your ground speed is 45. If now you turn off the wind your air speed drops from 45 *plus* 15, to 45 *minus* 15, and you drop with it." Now this explanation is not only contrary to the most fundamental principles of mechanics, but has the additional disadvantage that it leads to wrong conclusions. From it one would infer that if you could make a turn safely once, in a given wind, you would be safe in repeating it, whereas you are not. And from it one would infer that if you see whether you get any instability in a given turn at two or three thousand feet altitude, you will know what to expect near the ground, which again is not true, because this instability fails to occur except near the ground. The question is, What is the true explanation and how will you avoid this danger? And as one phase of this question, can you avoid it by "skidding" your turn, as shown in Fig. 3, the way many pilots do in such cases, and if you try this, is there any other danger caused by skidding?

As a fourth problem, let us consider some of the questions arising in landing. For example, if your motor stops and it is doubtful whether you can reach a field you want to land in, how shall you tell at what angle to hold the nose of the ship to make the flattest glide? And what effect does the wind have on your answer? Or if your landing field is almost directly below you, why can you descend faster in a "spiral" (or more exactly, a

helix) than you can in a series of long steep glides, without getting an excessive air speed? Or if the line to your field is steeper than you care to glide, why can you shorten your glide by turning the nose from side to side with the rudder, the wings being level, and making a series of short "skids"? And is there any danger in this process? Or, why, under such circumstances,

FIG. 3.



Illustrating forces in a skidding turn.

can you get the same result by banking the ship, without allowing it to turn, and sideslipping steadily toward the field? Is there any danger in this? And why is sideslipping preferable to skidding? And is it better to come out of the sideslip by using the rudder or the ailerons? And if great accuracy is required in the length of your glide, is it safe to continue a sideslip till you are very near the ground? And if you approach the ground at a low

speed in an ordinary glide and try to level off for a landing, why does the ship refuse to change its course as fast as you change the elevation of the nose, and settle below the course you steer for, often landing with something of a shock unless you allow for this effect?

A fifth type of problems is that of the effects of gusts—"bumps," "holes in the air," etc.—both in the motions of the machine and in the strains introduced by them.

A sixth type of problem is connected with stability and includes such questions as these: At what speeds is a ship most likely to be longitudinally unstable, and does every ship insist on diving if the speed is reduced to the "stalling speed"? And how is the longitudinal stability and the action on stalling affected by changes in the position of the load? Why does the ship tend to roll easily at low speeds and especially on stalling, and why do the ailerons lose their effect at slow speeds and actually reverse it at a speed just above the stalling point? And why, in making a turn at the proper angle of bank, does the ship tend to increase its bank and have to be held from doing so by the ailerons? Is this ever a source of danger? And in rough air do you lose more speed by allowing the ship to get off its course and bringing it back at your leisure or by constantly watching for bumps and correcting them quickly? And what is the relation of the mathematical theory of stability to practical flying?

Finally, we have the questions of acrobatics. What are the various "stunts" and why do certain motions of the controls produce the effects they do? Why should all controls be moved slowly and easily, and to which ones does this rule apply most strongly?

Now these questions are all highly practical problems on the application of the laws of physics, and every good pilot must answer all of them, and many more, except perhaps those beginning with "why." Three important general questions are, therefore: how can he answer them without knowing physics; what is the value of the questions beginning with "why"; and what is lacking in our text-book physics that makes it of little value in the art of flying?

The answer to the first of these questions is this—by long practice and observation. Hence the great stress laid by pilots on the number of "hours in the air" that a man has had. There are so

many of these questions and they are all so varied by minor factors, that if they must all be answered by this empirical method, very many hours are indeed necessary. But with the cost in the neighborhood of a dollar per minute, this is not the ideal method of study. Nor is it free from danger, though it must be remembered that flying is far from the dangerous occupation it once was, even to a novice. However, anything that lengthens the period when a man is uncertain as to what will happen or what to do next is unpleasant. This uncertainty can be avoided to some extent by acquiring a rather artificial self-confidence and habit of forming very positive opinions, and the result is positive action in any case, which is much better than any hesitancy even if it is not the best action. But even this procedure has the disadvantage of making a man feel like the "King of the Air," as one pilot expressed it to me. The "divine right of kings" is not so popular as it once was, and abdications are usually sudden.

These facts answer also the second question, on the value of the "whys." The difference between empiricism and science is the existence of "whys" in science, and these scientific connections between facts are just what we need to avoid the troubles just mentioned.

Now as to the third question, the trouble with the text-book physics. On the problem of climbing to 10,000 feet, outlined first in the above collection, the text-book methods are fairly good and the principles are all there. We have merely to calculate the power available at any given air speed and the power required by resistance and subtract to get the power used against gravity. This can be done on the ground, if the data are available, and the best air speed can be determined. Or, more exactly, it can be figured approximately and we can make sure that the same air-speed will be best under the same conditions in different flights, and use a value determined by experiment. As to what instrument to use for identifying this speed, we can show that the air speedmeter is best because its reading is almost the same for the best climbing rate under many different conditions, while that of the spirit level is not so. This problem, then, is one that can be fairly well solved by the text-book methods. The problems of navigation likewise come in this class and on such problems the navigating instruments including the airspeedmeter, are invaluable aids. This makes these instruments, in fact, almost as

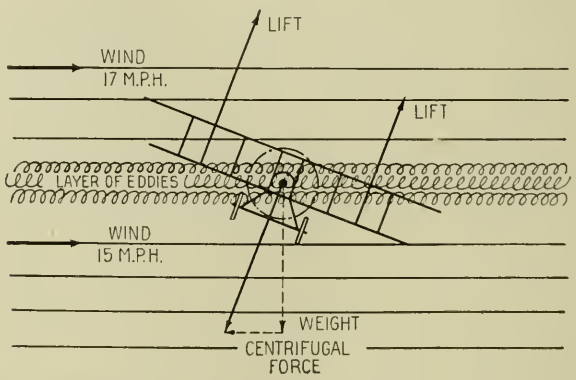
important as the tachometer, oil gauge and thermometer on which the pilot depends for a knowledge of the conditions of his motor. But these are not all the problems of flying.

When we come to the zooming problem, the case is different. Conditions are more complex, and there are not only more major factors in the problem, such as the distance across the field, the height of the obstacle, the speeds of the machine and the wind, the rates of climb at different speeds, the forces introduced by the accelerations in the zoom, and others, but there are also many minor factors, such as small unexpected irregularities of the ground the machine runs on, gusts of wind, etc. And above all, there is no time to figure anything, and the pilot must have his eyes outside the ship and not on any instruments, and therefore can have no numerical data to figure from, as well as no time to figure with even the simplest formula, and no simple formula that can possibly take account of even the major factors. The neat little quantitative problems of the text-books, with exactly three data when the formula calls for three, and the formula only two pages back, are poor training indeed for the application of physics to such a case as this. But the result must be none the less exact for lack of arithmetic, and the pilot must know by intuitive reasoning in a few seconds the answer of a problem insoluble by arithmetic in a few hours, and know it better than arithmetic would tell him.

In all the other problems stated above the case is the same, and one of them, especially, brings out another point. If we apply the text-book methods to the problem of turning off the wind, we would say that the principle of relative motion would settle it at once, and that there was no reason at all why a turn off the wind should make the machine act differently from one turning into the wind at the same air speed, the ground speeds only being different. But the fact is that the difference, if you are near the ground, is large and important, and this difference is due to what seems like a minor factor. Namely, the wind is likely to form rather sharply defined layers, of different speeds, the higher ones moving faster. This effect has been known to sailors for centuries. In this case, if the machine is banked in the turn and strikes the boundary of two such layers, it may easily be tipped over by the difference of speed of the wind on the wings, as shown in Fig. 4. This explanation, which was sug-

gested to me by Dr. W. J. Humphreys, accounts perfectly for the observed facts. The question of the advisability of skidding this turn will be discussed below. The point of importance here is the grave danger of following the usual text-book procedure, of cutting off all the minor factors of the problem, perhaps without even mentioning them, solving a much simplified numerical problem, and then completely forgetting to make any attempt to find how the minor factors would modify the result. It has become so customary to consider a quantitative answer as the sure indication of rigorous thinking, that we sometimes forget that correct qualitative work is much more rigorous than incor-

FIG. 4.



Illustrating forces introduced by striking different wind layers in turning off the wind.

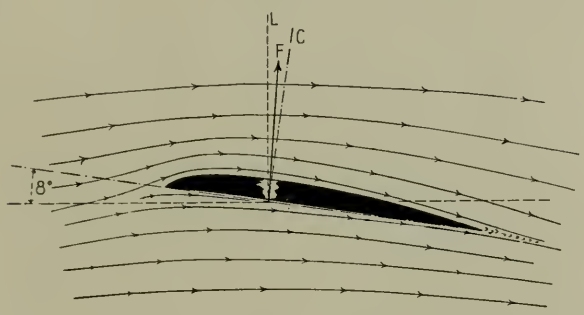
rect quantitative, and that figures can lie, in spite of the proverb, if we lie to them first about the data. Even if truth were not the *raison d'etre* of rigor, it would still be better than a mere appearance of a rigor that is not there.

In the physics of flight, then, we must formulate our laws in such a way that they can be used quickly and accurately, with not much regard for the possibility of numerical work, and if possible we must reduce them to a basis either of familiar fundamental laws of mechanics or of something the pilot can quickly verify for himself. And above all they must be such as to allow the introduction of minor factors and they must replace the quantitative element that appears in engineering as arithmetic by a fine sense of proportion and a clear, rigorously correct, though non-arithmetical, analysis of the problems.

FUNDAMENTAL PRINCIPLES.

The supporting forces and resistance of the wings depend on the flow of air past them, and if the character of this flow is understood it should be easy for the pilot to understand the behavior of the machine. Now the character of the flow is itself easy to observe, by simply tying small bits of tape to various parts of the wires. One may observe the directions of flow from the way the tapes stand out in the wind, and thus form an idea of the stream lines. And one may see differences in the speed of the air at different points by the speed of fluttering of the tapes. If tapes on the wires do not satisfy one's curiosity, the observations may be extended by rigging sticks in other places with tapes on the ends of long nails stuck in them.

FIG. 5.



The results of such observations depend greatly on the angle of incidence, or angle of attack, which is the angle between the wing chord and the line of flight, but they are of course independent of the angle of either line to the horizontal.

For a moderate angle of attack, such as we would use in climbing, the stream lines around a good wing are approximately like those shown in Fig. 5. If we define a normal speed to be that at a long distance away from the wing, we find a higher speed just above the forward part of the wing and a lower speed just below it, while conditions are more normal, or perhaps slightly reversed, near the trailing edge. This is as we might expect, since the stream lines over the top of the wing must diverge to fill the space over the trailing edge, and those below the leading edge must converge. Now we may estimate the pressures involved in either of two ways. One, less familiar and less con-

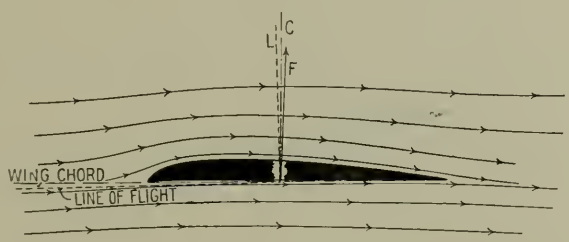
vincing to the novice, is by Bernoulli's theorem, that makes the pressure low wherever the speed is high in a stream line not exposed to friction. This means suction on top and pressure below, both especially strong on the forward part of the wing. A more convincing method is to consider the centrifugal effect due to the curvature of the stream lines, which obviously involves a strong suction on the strongly curved part of the upper surface, and a fairly good pressure on the forward part of the lower one. This looks at first like a different effect from Bernoulli's, and as though we should add the two, but a closer examination would show that Bernoulli's principle, in the restricted form given above, refers to the difference in pressure at points *along* a stream line, while the centrifugal analysis refers to a difference *across* the stream lines, so that these differences are not in such positions as to be added. By either method alone, we may compute the pressure at any point by reference to the pressure at points very far from the wing. Another fact that is important, illustrated in Fig. 5, is that the stream lines ahead of the wing are not parallel to the line of flight, but inclined distinctly upward. This is a point on which I have taken exact measurements, and it is confirmed by experiments of other observers. According to my measurements the inclination of the stream lines to the true line of flight, at one chord length ahead of the leading edge in a Curtiss JN4H is about one-half the angle of incidence, whatever value that angle may have. That is, an incidence indicator at this point always reads about 50 per cent. too high. The explanation is probably that the downward motion of the air behind the wing forces an upward motion ahead and on the sides. The importance of it to us is that it increases the curvature of the lines and the resulting centrifugal effects.

Another important point is that since the centrifugal effect is strongest on the strongly curved part of the upper wing, it is important to have most of this curvature occur in a region where the normal to the surface is inclined forward of the normal to the wing chord, as it is in the forward part of the surface. Since the suction is normal to the surface, this makes the strongest suction on the wing have a distinct forward component, thus balancing much of the backward force offered by other parts. This accounts for the superiority of wings that are thickest at a point well forward of the centre, and also for the fact that the

resultant force is inclined forward of the normal to the chord as shown in Fig. 5, although, of course, it is back of the normal to the line of flight. It is most important to have the resultant force inclined backward as little as possible because it is the component of this force backward along the line of flight that makes us need a motor, and we may congratulate ourselves that in spite of the yielding nature of the air this component may be made not much larger than if the machine were sliding on a greased metal surface. The component upward, perpendicular to the line of flight, will be referred to hereafter as the "lift" and the component backward, along the line of flight, as the "drag."

As the angle of incidence is *reduced* the action of the lower surface is obviously weakened, and the space to be filled by the stream over the upper surface is reduced, as shown in Fig. 6. At

FIG. 6.

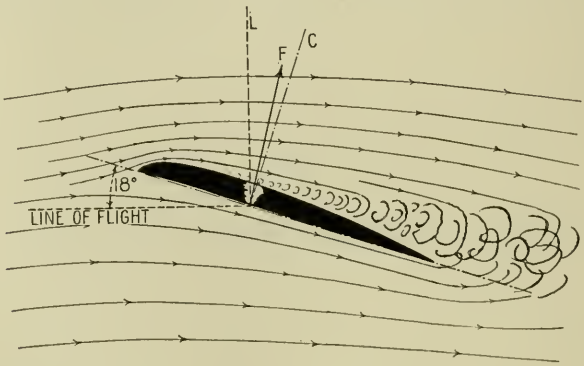


the same time the upward motion ahead of the wing is reduced, and a downward pressure appears on a narrow region near the leading edge, where the air is deflected upward by it. The result of all this is to weaken the lift and to a less extent the drag, at any given speed, and also to shift the centre of pressure back along the wing. Now the weakened lift at a given speed means that small angles of attack can be used only at high speeds, and the shift of the centre of pressure is such as to make a machine whose speed is increased tend to dive and increase it more. This shift of the centre of pressure produces a tendency to longitudinal instability, that must be corrected by other features in the design.

On *increasing* the angle of incidence above a moderate amount, the effects are at first practically the reverse of those found in reducing it, though the drag soon begins to increase faster than the lift and the centre of pressure becomes almost stationary. But at a certain angle the space above the back of the wing be-

comes too large to be filled by the stream lines over the top without causing a suction so great as to draw air in from other regions, especially from the crowded stream lines just below the trailing edge. If this angle is approached gradually by slowing the machine, and you have a piece of tape on a wire near the surface of the wing at the foot of one of the rear struts, you can see this tape cease its rapid fluttering, settle for an instant on the surface of the wing, and then tie itself up in a tangle, showing the formation of a mass of eddies. Just as this happens, the wing loses its lift and the machine starts to fall. At the same time it dives, showing that the centre of pressure has shifted aft, and the loss of lift was mainly on the forward part of the wing,

FIG. 7.



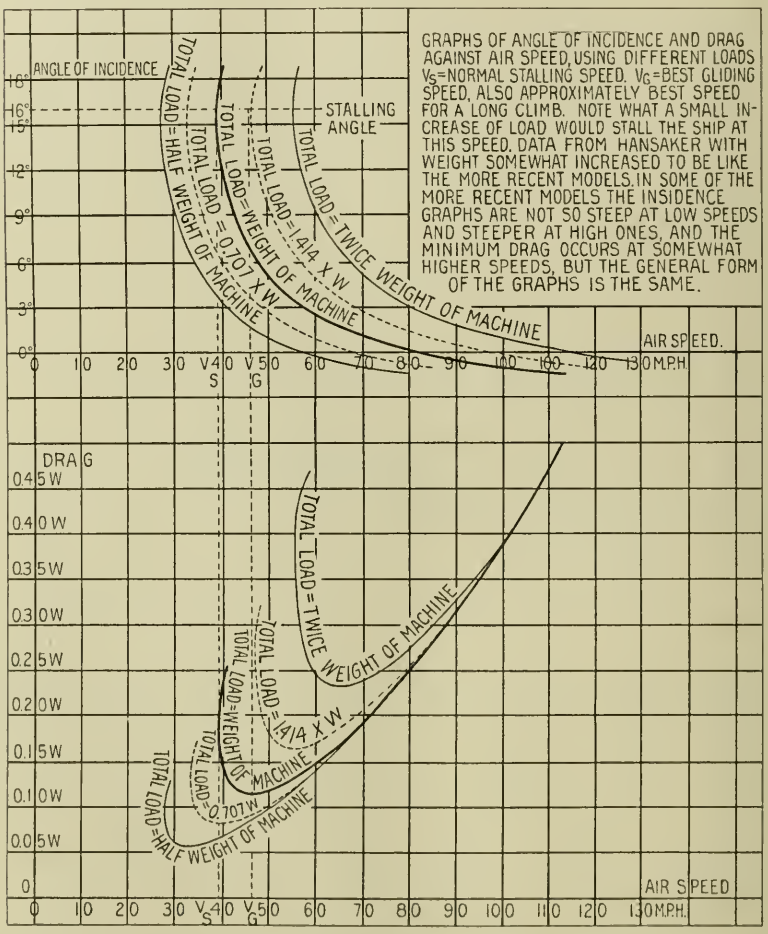
where the tapes are still fluttering as before. The explanation is simple. The stream lines over the top of the wing no longer have to fill all the space over the back, and have lost some of their speed and much of their curvature, as shown in Fig. 7, and much of their centrifugal effect is lost. Incidentally as the forces on the wing due to these stream lines had a forward component as well as an upward one, their loss means an increase of drag as well as a decrease of lift. This behavior of the wing is called stalling, and occurs at a definite angle for any given form of wing. For the forms in common use the stalling angles are between 13 and 16 degrees. On increasing the angle of incidence beyond the stalling angle, the mass of eddies gets thicker, the lift decreases more, while the drag increases. These changes may be followed easily by watching the tapes on the wires.

The most noticeable fact about the motion of an airplane just before it stalls is the lateral instability that serves as a warning of the stall. This lateral instability increases during the stalling process because, if either wing stalls before the other, it drops down and holds back at the same time, thus increasing its angle of incidence and stalling it all the more. If this process is allowed to continue, that wing will remain stalled while the other one keeps its normal motion through the air, and the result is a tail-spin. In fact, the tail-spin may be distinguished from the spinning nose-dive by the fact that in the tail-spin the inner wing is stalled, although the speed of the machine increases to considerably more than the ordinary stalling speed. An important point that is explained readily by the motion of the air over the wing is the reversal of the action of the ailerons that occurs during a stall. If the aileron of a stalled wing is tipped down it is obvious that the eddies over the back of the wing will be increased and the wing stalled even more than before, whereas if it is tipped up the wing tends to recover its normal motion through the air and lifts more than if the aileron were straight. This may be seen best by gliding the ship almost stalling with the rudder straight and throwing the ailerons hard over. She will then spin in a direction opposite to that one might expect if the ailerons acted normally. This is sometimes called an "aileron spin."

One of the fundamental characteristics of centrifugal force is its proportionality to the square of the speed of the body it acts on, so long as the radius of the path is the same. If, then, a wing can be made to take the same angle of incidence at different speeds by using different loads on it, and if the stream lines are the same in both cases, then we may expect the forces both of lift and drag to vary as the square of the speed. This, in fact, is what they do. This law of the square of the speed may be deduced also from the analysis by Bernoulli's principle, or by the theory of dimensions, a branch of mathematics that is much neglected by most engineers and many physicists, but very useful in such problems as this. By any of these methods we may likewise show that the law will hold only if the shapes of the stream lines are independent of the speed. Because it does hold, any reasonable angle of incidence can be used in steady flight with any load, provided the speed is properly adjusted, and at any given angle of incidence the ratio of lift to drag has a definite value, and hence

the drag at a given speed is calculable from the load. We may therefore plot a series of graphs of incidence and wing drag against air speed for different loads. As the resistance of other

FIG. 8.



parts of the machine, the "parasite resistance," at a given angle of incidence, is also proportional to the square of the speed, we may add it to the wing drag, and plot the total drag against the load at different speeds. The form of the resulting graphs may be predicted qualitatively from the above theory, but for

definiteness we shall use some quantitative data, shown in Fig. 8. These are calculated from some data on a model taken by Hunsaker in the wind tunnel at the Massachusetts Institute of Technology and published in the Smithsonian Miscellaneous Collections, vol. 62, Nov. 5, 1916.

SOLUTIONS OF CLIMBING AND LANDING PROBLEMS.

We are now in a position to solve at once many of our climbing and landing problems. Take first the problem of a slow landing, where the observed fact is that if you level out for a landing from a slow glide, your machine settles distinctly below the direction you steer it for, and may land with a shock unless you allow for this settling. As a slow landing is required in any very small field, it is of some importance to understand the nature of this phenomenon. If you glide slowly, you are using a large angle of incidence, perhaps not far from the stalling angle. Now if you try to level out, you introduce an upward acceleration, and (using d'Alembert's principle) a downward centrifugal force, thus putting an extra load on your wings. This, according to Fig. 8, requires a change of angle of incidence to a higher value, and hence results in a motion of the machine in a direction below that which you would expect it to take if you were not looking for such a change. In fact, if you try to level off too quickly from a glide too slow, your machine may even stall at a speed above the normal stalling speed and settle much quicker than you expect, hence landing with a shock. This makes it somewhat unstable laterally, as is always the case in a stall, and is liable to make you break a wing-skid.

Another problem involving an angle of incidence increased by a centrifugal load, is that of the "spiral" glide. In such a glide, a steep descent may be made without excessive speed. Here the load is the resultant of gravity and a centrifugal force not vertical, but the load is greater than if gravity alone were acting. Hence, by Fig. 8, the drag is greater. It is this increased drag that prevents a high speed on the steep spiral descent.

A more difficult problem is that of zooming over a telegraph wire. The effect observed is that if you climb at the normal best climbing position until the last moment and then zoom, you can not gain more than a very few feet in the zoom, whereas if you fly more level first, at a sacrifice of initial altitude, you can some-

times clear a point perhaps ten feet higher than by the first method. Either way is far from safe, and the method of zooming is not always the best, and if it is done at all, the nature of the trick should be understood. First, if you climb steadily at the best speed, you pick the speed where the difference between the power available and the power required is a maximum. At this speed your angle of incidence is about 6 to 8 degrees in most machines. Now suppose you zoom. You introduce an upward acceleration, a downward centrifugal force, and the result is much like that of the problem of levelling out from a slow glide. Any attempt to zoom high under these conditions is sure to result in a stall. But if you fly more level at first, and gain a higher speed, your wings can lift a heavier temporary load of centrifugal force and you can zoom higher. Moreover, when you clear the telegraph wire you can be making a downward curve, thus lightening your wing load by an upward centrifugal force, and you can go at a speed distinctly lower than the normal stalling speed without stalling. The height you can attain is determined by the total energy available from your motor in the flight minus the loss due to the drag and minus the kinetic energy at the top of the curve. Hence the best results are obtained if you do not fly too fast at first and lose too much because of drag at that time, but fly fast enough to avoid great losses due to drag when you carry the centrifugal load, and if you reduce your speed at the top to the lowest value you dare to use. With regard to this last point it may be noted that at low speeds and high angles of incidence a small upward gust may make a considerable difference in the direction of the relative wind and even cause a stall. Thus, instead of supporting you more than still air, such a gust may have just the opposite effect, and if it is uneven on your wings it may throw you into a spin.

These points may readily be tested experimentally, though for obvious reasons a small fracto-cumulus cloud is a better object for the experiments than a telegraph wire. By this method, or by noticing how restricted the conditions are when the above theory indicates any gain by zooming, one may readily prove that under many circumstances a zoom does more harm than good, especially if the obstacle is a low one at a distance too short to allow the machine to get up a reasonable speed for the centrifugal

load to be carried. In my opinion, much of the zooming that is done is either useless or worse.

To solve the problem of steep descent by means of a series of skids or a long, steady side slip, we must consider several factors. One is the obvious increase of parasite resistance when the fuselage moves along any line but its axis; another is the effects of the eddies due to the side motion of the fuselage in reducing the lift of the wings on the leeward side, and a third is the increased "end effect" or escape of air past the ends of the wings from below, and converging motion of the air above the ends. This last effect is an obvious result of the increased pressure below the wings and reduced pressure above them and is greater if the wing is shorter, or if it is equivalent to a shorter wing as in a side-slip. As all these effects increase with increasing angle of the line of flight to the fuselage they can be used to give a readily adjustable drag and make it possible to regulate accurately the length of the glide. As the side-slip is steadier than the skids, it is easier to form an exact idea of one's course by this means and regulate it accordingly. Incidentally, we may notice that the same considerations serve to condemn the practice of side-slipping continuously in flying across the direction of the wind, so as to neutralize the cross component of the wind. The wings should be level and the course changed toward the wind.

With regard to the possibility of danger in these methods of landing, we must consider only what happens if the speed is reduced to the stalling point. Now it is obvious that the presence of eddies from the fuselage over a part of one wing tends to make it easier for the eddies to spread on it, and that the end effect of the wing that is to leeward (in the relative wind) is such as to weaken the lifting power of this wing especially. Moreover, on account of its weakened lift, as well as other factors in most designs, the ailerons on this wing must be turned down to hold this side up, and the ailerons on the other side are up. All these factors combine to make the leeward wing stall when the windward one is nowhere near the stalling point. And when it does stall, with the other wing still lifting normally, it will drop very suddenly, thereby increasing its angle of incidence still more, while the increased drag on it makes the ship spin round. The result of stalling from either a side-slip or a skid is therefore a

quick tail-spin. In the case of the side-slip the leeward wing is the upper one, and it falls suddenly below the other, drops backward and becomes the inner wing in the spin, while the other one keeps its low angle of incidence throughout the spin and does not stall at all, as one may readily prove by watching the tapes. In the case of the skid, the inner wing in the skidded turn is the leeward one, and we have in addition to the other factors the difference of speed of the two wings. The drop of the leeward wing is therefore even more sudden than in the side-slip, and in fact, forms a most spectacular trick on that account. Because of it, we may say that the practice of skidding to shorten a glide is not to be recommended, though a side-slip, if not made at too slow a speed, is quite safe.

As to the question of whether to stop the side-slip by righting the machine with the ailerons or by steering into the direction of the relative wind with the rudder, the above considerations show that the former method would mean a loss of speed before the slipping stopped, and the latter is the safer way.

We may now answer the questions of the advisability of skidding a turn off the wind, or of side-slipping till the last moment in landing. If we skid the turn off the wind, we would indeed avoid putting the two wings into different wind layers if the layers were flat and free from eddies. But this is too much to expect of them, and if there are eddies they will tend to throw the machine into exactly the type of spin that it tends toward because of the skidding. This practice must therefore be condemned without qualification. In side-slipping for a landing, on the other hand, if we do meet any such wind layers their chief result will be to level the wings and reduce the amount of slip, which does no harm. But as these are not the only types of irregular winds to be met near the ground, the air speed should not be reduced too near the danger point. As a French officer once said to me, "The first thing in aviation is to *fly*. To fly you must have speed. You *fly* into a house and live. You *fly* into a tree, and you sit there and smoke a cigar. But you *spin* into the field, and you are killed."

The problems on the effects of gusts of wind need not detain us long. The simple questions of the forces and accelerations when a gust is first struck are matters of finding the changes in the speed and direction of the relative wind, and the subsequent

motion involves stability considerations. The mathematical treatment of these has been given in detail by E. B. Wilson on the basis of the stability theory of Bryan and Bairstow, and even a qualitative treatment would be too long to insert here. One qualitative point that is of interest is that badly disturbed air, such as is found over hot sandy country, will tend to make the stream lines irregular and fluctuating, and produce more drag for a given lift, thereby requiring more power and greatly reducing the speed and climbing power.

THE ELEMENTARY THEORY OF STABILITY.

The theory of stability, from the pilot's point of view, is the answer to questions of this type: If the machine is flying steadily and is disturbed by a momentary gust, will it return to steady flight if I hold all controls fixed, and if so, how soon? Or if not, will it do so if I move only one control, the others being fixed? And which one? And what type of motions will occur? And how quickly ought the machine to return, if it does so at all? There is, of course, also the question of whether it would return to normal flight with the ailerons and elevators free instead of fixed, as some machines will. In machines with one motor the rudder can never be left free, because the secondary effects of the propellor torque would always turn the machine one way, so the question of a free rudder does not enter.

Of the various possible arrangements of the controls and resulting types of stability, we may define four as of the most practical value in piloting, as follows:

(*a*) Longitudinal, or pitching, stability. If a machine is made to pitch slightly, but does not yaw or roll, and the elevator is then held neutral, will it return to its initial elevation of the nose, or will it go either into a stall or a dive?

(*b*) Directional, or yawing, stability. If it is made to yaw slightly, but does not pitch, and the ailerons are so moved as to prevent rolling, and the rudder is then held in the position for normal flight, will it stop yawing and settle down to a straight course?

(*c*) Rolling stability, sometimes called "lateral" stability If it is made to roll slightly but does not pitch, and the ailerons are then held neutral while the rudder is so moved as to keep the axis of the ship pointed in a fixed direction, will it right itself?

(*d*) Complete lateral stability. If it is given any combination of slight rolling and yawing, but does not pitch, and both the ailerons and rudder are then held in positions for normal flight, will it return to normal flight?

One might expect at first that rolling and yawing stabilities, occurring in the same ship, would involve complete lateral stability, but as we shall see below, they do not. It is assumed in the question on pitching stability that the machine does not roll or yaw, and in the others that it does not pitch. For very small motions, this involves no outside interference, but for motions not very small there is usually enough connection between the types of motion to make it necessary to use the controls to prevent pitching if yawing or rolling occurs, and if large amounts of pitching occur the controls are needed to prevent the other motions.

The first problem is qualitatively simple. As noted above, the shift of the centre of pressure with speed is such as to produce instability in pitching. But suppose the horizontal tail surface, or "stabilizer," is large and set at a zero angle of incidence for a certain condition of flight, where the wings have a reasonable positive angle and the centre of pressure is at the centre of gravity. As the stabilizer is far back of the centre of gravity, it will act as a weather vane and tend to hold the ship to this angle of incidence, irrespective of its speed. Therefore, if the speed is too high for normal flight with this angle, the machine will nose up and then begin to lose speed, and if it is too low, the reverse effect takes place, the machine finally settling to a straight course at the proper speed for this angle of incidence and the proper angle of climb or glide to give this speed with the available engine power. The essential point is to have the tail carry little or no load, so that it will tend to bring the ship to the same angle of incidence at any speed, and have it large enough to do this in spite of the shift of the centre of pressure. The same thing could, in fact, be accomplished with a smaller tail set at a negative incidence, but then the correction of any deviation from a normal course would be too quick, and gusts near the ground would cause danger in landing. A large tail with no lift gives a slower correction and damps out any oscillations rather better.

With such a tail, a momentary pitching disturbance results in a combination of two oscillations, one so heavily damped as to be nothing but a "bump," and the other a long slowly damped

wave-like course, with higher speed in the trough of the waves and lower on the crests. Lanchester calls this long oscillation a "phugoid," and in 1894 he made model airplanes that he called "aerodones," based on practically the theory outlined above, and showed that they were longitudinally stable and would perform phugoids if left to themselves. A more exact mathematical theory has been developed by Bryan and Bairstow, as a fourth order differential equation, describing both oscillations and also indicating the large non-lifting tail as the condition for decreasing amplitude in the phugoid.

The mathematical theory indicates that a slight phugoid motion is sometimes stable at high speeds and slightly unstable at low. (See Hunsaker, "Dynamical Stability of Aeroplanes," Smithsonian Miscellaneous Collections, 1916.) Practically, however, if you try to hold the elevator fixed, by hand, the order of stability often seems to be just the reverse. The explanation of this is probably that you do not really hold it fixed. The greater rate of shift of the centre of pressure with speed at high speeds means a greater rate of change of the tail load if the elevator is fixed. Consequently, the lost motion and elasticity in the control wires and levers and in your muscles probably permits enough motion of the surfaces in response to this changing load to produce the apparent instability. In a ship with an adjustable "stabilizer" or horizontal tail surface in front of the elevator, you find the stability with the elevator left free to be of the same sort as that predicted by the theory. This example shows the importance of a clear and definite statement of the conditions of the problem if a definite answer is desired, and the importance a minor factor may sometimes acquire.

Yawing, or directional, stability is likewise a matter of weathervane action, but in this case with a vertical tail fin and rudder. But here, as we do not have any strong tendency to instability, like the shift of the centre of pressure, the weathervane surface can be made smaller. In fact, in birds it is not even present, being made up by the freedom of motion of the wings, though the horizontal tail surface always is there. The motion in the case of a momentary yawing disturbance in most cases is a single type of damped oscillation, of a period of 5 or 10 seconds, though at the stalling speed, as noted above, all lateral stability disappears. I have flown machines of one type where the yawing motion was

not oscillatory, but the machine would continue to skid indefinitely around a large circle, the speed of skidding neither increasing nor decreasing. In these machines the rudder and vertical fin were unusually small.

To give rolling stability we may use either a dihedral angle between the wings, retreating wings, or high vertical fins, as described in all the elementary treatises on airplane design. In any case, whether stability exists or not, the first rolling motion is damped out in a fraction of a second by resistance. This we might readily predict from the increased angle of incidence of the wing that is going down and the decreased angle of the other one. This leaves the ship banked up. If now, as we assumed above, the rudder is used to prevent yawing, the machine will side-slip downward and may or may not right itself. If it does, it will do so only very slowly, because of the great resistance to rolling motion. If the ship is excessively stable against rolling it will right itself fast enough to side-slip further and then come back again, making a damped oscillation, but in most ships the motion is dead beat. Whether it rights itself at all or tips further from the start, the rolling is always slow. Consequently, rolling instability is not ordinarily a source of danger, as yawing or pitching might be. It is, however, a convenience in a long cross-country flight, to be able to sit back with your hands on the cowl and steer by the rudder only, as you can in a ship that has both rolling and pitching stabilities with free controls. But if you make turns by the rudder only, as one may infer with little labor from the theory above, there are great losses of energy in skidding and side-slipping. And another point deducible from the theory is that any of the devices for securing rolling stability mean a great increase in the "end effect" on the wings at low speeds, and consequent loss of climbing power, and too much rolling stability means unsteady motion in gusty winds. Many recent models are therefore almost neutral as to rolling.

Now let us consider the question of complete lateral stability. If the machine is disturbed by a slight yawing motion only, the weathervane action of the fixed rudder will tend to produce the same damped oscillation that it would with the wings held level, and the motion will not differ very much from this. The only noticeable difference is that since both wings must lift almost

exactly the same (rolling moment of inertia being small) the wing swinging forward will take a smaller angle of incidence than the other, and consequently rise during the forward motion, while the other drops. The peculiar type of motion described here has been called by Hunsaker the "Dutch roll." This rolling motion introduces a turning moment which tends, in many cases, to retard the wing with the smaller incidence. This seems strange at first, but was deduced mathematically by E. B. Wilson, and may be qualitatively confirmed from the theory above with careful thought. The effect, however, is not ordinarily enough to make a very noticeable change in the period of oscillation, though it must make some. The ships mentioned above, that were neutral as to pure yawing, seemed to be slightly stable in the Dutch roll, but so slightly that the rudder was always busy in rough air and many pilots regarded them as liable to fall into a spin. This idea was not justified, but the continual work with the rudder was annoying at times. Now the Dutch roll may be called a fundamental type of motion, like the phugoid, because all the velocities, yawing, rolling and skidding, decrease in the same ratio as it dies out.

Another fundamental type of motion is obtained by an impulsive motion of the ailerons and rudder to cause a rolling motion, with a slight backward motion of the wing that goes down. This is always quickly damped, like the initial motion described under the heading of rolling stability, and in fact so quickly, that it is hard to tell what ratio of rolling to yawing constitutes the fundamental type in question. This motion is never oscillatory.

Finally, there is a curious spiral motion, consisting of a long slow turn somewhat overbanked, with a steady side-slip toward the centre. In this it is most difficult to get stability, or decreasing disturbance from straight flight, because of two factors tending to increase it. One of these is the greater lifting power of the wing on the outer side of the turn, due to its greater speed. In a steady turn this wing must be held down and the other one up by the use of the ailerons. But with the ailerons neutral the outer wing must tend to rise unless something prevents it. Consequently, if the machine is turning steadily and the rudder and ailerons are put in the neutral positions, the outer wing will begin to rise. The machine will then side-slip toward the centre; and

if the rudder is large enough to produce yawing stability it will then begin to yaw faster and then bank up faster still. ("Yawing" means any turn on an axis set vertically with respect to the ship, and does not necessarily imply oscillation as it does when applied to a sailboat.) These two tendencies work together, therefore, to produce spiral instability. But if the machine has rolling stability the same side-slip that produces quicker yawing will also tend to reduce the bank. And if it has great resistance to yawing due to vertical surfaces far ahead of and behind the centre of gravity, it will not start to yaw fast in obedience to a given side-slip. Bryan's fourth order differential equation for complete lateral motions predicts all the three fundamental types of motion just discussed. In it the criterion for spiral stability appears as the difference between two products, each of two "resistance derivatives." The two resistance derivatives in one product express the rolling moment due to yawing and the yawing moment due to side-slip, and the two in the other express the rolling moment due to side-slip and the yawing moment due to yawing (the last, of course, being a damping coefficient of yawing, and therefore negative). The theory therefore predicts exactly the type of performance observed in the air and qualitatively explained by these simpler considerations, and indicates the same conditions for stability.

As a matter of fact spiral instability, like rolling, produces only a slow growth in the motion involved unless the ship is of an extremely bad design, and it is therefore not worth sacrificing much else to correct. It is less important, for example, than the Dutch roll. The ships I spoke of above that were neutral as to yawing, with the wings held level, were also spirally neutral, and with all controls neutral they would circle indefinitely, side-slipping inward continuously. Some others that I have tried would do the same and have yawing stability, but many models with stability for both rolling and yawing are spirally unstable, and true spiral stability is very hard to obtain without too much of the same sacrifices that must be made for rolling stability.

CONCLUSIONS.

The factors involved in these qualitative stability considerations are not especially complicated, and are practically the chief factors that must be determined quantitatively in designing an

airplane according to the mathematical theory. As a matter of practical piloting, the chief value of the study of these points is in the fact that if the pilot understands why the machine performs the motions it does under these definitely specified conditions, and has picked out the factors involved in each and analyzed them carefully, he will know how to recognize their action in other cases, to correct them if necessary and to use them if possible, and the actions of the airplane will cease to be those of a capricious animal, and become as reasonable as anyone can wish them to be. To attain this understanding it is not necessary to go into all the details of the algebraic statements of these laws, but it is necessary to keep the fundamental principles of the wind forces in mind, and above all it is necessary to state definitely and rigorously the conditions of each problem and the factors involved in it.

In the study of the theory of acrobatics the problems are of a very similar nature, the chief additional factor being the changed character of the forces introduced when one wing is stalled and the other not, as in the tailspin. A detailed discussion of acrobatics is hardly necessary here, as no new principles or methods are involved and the chief object of this work is to point out the necessity for the type of analysis of the fundamental principles that is outlined above and the great need for rigorous thinking without arithmetic.

By this I do not mean to say that arithmetic has no place at all in flight, because, as noted above, the problems of navigation and long climbs involve its use, although even here I should say that only the simplest approximate rules are of much real value. Nor do I mean to imply that instruments for quantitative measurement have no use. In fact, I have spent many hours in the air experimenting on such instruments and am fully convinced that they can be of the greatest aid in problems of navigation and long climbs as well as in showing motor trouble in advance. But these problems are emphasized enough in the treatises on airplane design, and here I am concerned with the qualitative problems that are of at least as much importance, if not more.

They are a type of work that is sadly lacking in our physics text-books and courses, and consequently in the students. We try to cover so many topics in our courses that the student and even the teacher are almost driven to clutch at a formula like the proverbial drowning man, and with much the same result.

If physics is the study of inanimate things, then it *is* the study of things, and not of numbers; and if things choose not to lend themselves to numerical analysis, that does not mean they are not worth studying. And airplanes, as noted at the beginning of this paper, are not the only inanimate things that sometimes make this choice. If things as they are can be understood best by correct analyses of a few typical subjects, quantitatively where things lend themselves to quantitative work, and qualitatively but rigorously elsewhere, then let us change our courses to make such analyses.

Caking of Salts.—This phenomenon has been studied by T. MARTIN LOWRY (*Chemical Trade Journal and Chemical Engineer*, 1920, lxvi, 297–298). Marked caking of ammonium nitrate may occur when the crystals are dried in a commercial drier, or when the molten salt containing a small per cent. of moisture is poured at a temperature slightly above the melting point of the dry salt; distinct caking may take place if the milled salt be left under slight pressure all night. A change in the crystalline form of the salt liberates inclosed moisture which then cements the tiny particles. Mechanical disintegration may liberate moisture and thereby produce caking, but to a lesser extent. In an edge-runner mill, the moisture evaporates as rapidly as it is released by milling, and therefore has but slight effect; consequently, serious caking does not occur. The following compounds may undergo caking: Sodium nitrate, potassium nitrate, cupric nitrate, potassium chlorate, potassium perchlorate, potash alum, Rochelle salt, soda ash, common salt, borax, sodium sulphite, sodium hydrosulphite, sodium phosphate, citric acid, and tartaric acid. Certain directions are given for the prevention of caking: "Care should be taken to reduce to a minimum the number and amount of soluble impurities; when possible, the substance should be left in large crystals, as the fewer the number of points of contact, the smaller will be the tendency for the material to bind together; when a finer product is required the most satisfactory way of supplying it is in minute unground crystals; when a substance is specially required in a finely powdered form, there should be careful drying, with agitation after grinding; as far as possible the drying should be carried out at low temperatures; substances should not be packed hot unless all traces of moisture have been removed; steps should be taken to maintain a dry atmosphere during packing; care should be taken to prevent access of moisture to the substance after packing; and caking may be minimized by keeping the temperature as constant as possible during storage" J. S. H.

THE CONSTRUCTION DIVISION OF THE ARMY.*

BY

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THE subject upon which I am invited to address you this evening is the work of the Construction Division of the Army during the World War. This is a subject so far reaching in extent, embracing so many angles, and of such large significance, that I have devoted considerable thought to what phase of it I had best take up and what method of approach I should employ. In view of the fact that in 18 months the Construction Division completed or had under way 581 construction operations, located in every state of the Union, except Nevada, involving an expenditure of more than twelve hundred million dollars, it is manifestly impossible to give any detailed résumé of its operations, for its accomplishment is too vast to be made intelligible by the mere recital of statistics, and the spirit of its men and their remarkable teamwork is too elusive for the camera to record. Neither figures nor photographs can adequately tell its story.

The Construction Division of the Army is an independent staff corps. It has no relation to the Quartermaster Corps, nor to the Corps of Engineers, with both of which it is sometimes confused in the mind of the public. It is a separate entity, which had its genesis in the Construction and Repair Department of the Quartermaster General's Office. This small subdivision, before the war, was charged with the construction and repair work at the Regular Army Posts. In no year did it expend more than 15 million dollars. In 1916 it had prepared typical plans for temporary mobilization camps in view of possible trouble along the Mexican Border, but nothing had been done in anticipation of the extensive requirements made necessary by our entry into the World War.

Upon the declaration of war the immediate problem con-

* Presented at the joint meeting of the Institute and the Philadelphia Association of Members, American Society of Civil Engineers, held Wednesday, December 17, 1919, by Col. G. R. Solomon, Officer in Charge of Engineering Branch, Construction Division, U. S. Army.

fronting this Government was that of raising an army of millions and of providing accommodations for its housing and training. In the Regular Army Posts, scattered throughout the country, there was accommodation for less than 100,000 men in small isolated posts, totally inadequate for the training of men, in large groups. The task of providing camps and cantonments ready to receive the citizen soldiery as soon as it could be called to the colors was assigned to Colonel I. W. Littell, who was relieved of his duties as Chief of the Construction and Repair Division of the Quartermaster General's Office and placed in charge of the Cantonment Division. From this small beginning, with its force of three officers and less than 30 civilian assistants, there was developed the Construction Division of the Army. Its personnel was recruited almost entirely from civilian experts. Engineers, architects, construction men, material men, auditors and contractors were called to Washington and commissioned for a definite service. Every man was a picked man and his ability and reputation personally known to at least two members of the rapidly growing organization. At the signing of the Armistice there were 1429 commissioned officers in the Division, of whom less than a half dozen were officers of the Regular Army, and the civilian personnel totalled over 30,000 employees, and there had been employed on its projects more than 427,000 laborers.

With the growth of the Division came increased responsibility. Before the construction of the sixteen original army cantonments was well under way, the Division was directed to construct within two months' time sixteen additional tent camps for the National Guard, with a capacity of 684,000 men. Before any of these were completed, orders were received to build a Quartermaster training camp at Jacksonville, Florida, and ports of embarkation in the vicinity of New York, Norfolk and Charleston, so that the men when trained could be readily shipped to France.

On October 5, 1917, the Secretary of War directed that all construction work for the Army within the United States should be performed by the Construction Division. Under this order, work was done for every division and bureau of the War Department, involving every class of engineering construction, and costing more than 10 per cent. of the total expenditures made by this country for war. Because of the spectacular performance in connection with the construction of the camps and the publicity

given them by reason of their occupancy by men from all parts of the country, they are thought by the public generally to be the principal work done by the Construction Division. In matter of fact, their cost represents less than half of the total sum spent by the Division. In addition to housing accommodations for more than two million men, this Division built arsenals, storage depots, industrial plants, gas plants, proving grounds and other such projects for the Ordnance Department; hospitals, with a capacity of more than 121,000 beds, for the Medical Department; huge interior storage depots similar to the one in this city, and port terminals at Boston, Brooklyn, Norfolk, Charleston and New Orleans, for the Quartermaster Department; warehouses and flying fields for the Signal Corps and the Division of Military Aeronautics; mechanical repair shops for the assembling and repair of automobiles and trucks for the Motor Transport Corps; and embarkation and debarkation facilities for the Transportation Service.

A body of tremendous assistance to the Construction Division, especially in the early days of the war, was the Emergency Construction Committee of the Council of National Defense. Under the chairmanship of Mr. W. A. Starrett, of New York, later commissioned Colonel; Mr. Frederick Law Olmstead, of Boston; Mr. C. W. Lundorf, of Cleveland; Mr. M. C. Tuttle, of Boston, and Major William Kelley, of the United States Army, this committee laid down many of the fundamental policies for handling construction work. It was a "Ways and Means Committee," whose counsel was sought and valued. It was in part responsible for the wise decision to utilize every available construction agency which had been perfected by years of commercial competition, as a part of the working machinery of the Construction Division. By utilizing the large contracting firms of the country and their efficient organizations, it was possible to keep their trained personnel intact and to make available to the Government their experience and talent. There was the additional consideration of the necessity for stabilizing the economic and business life of the country and carrying these organizations through the period of war, rather than disrupt and destroy them by trying to organize their employees under direct Government control. The same policy was extended to include the consulting engineer, and on each large project there was employed an experienced engineer of national

reputation who, with his organization, took the fundamental plans supplied by the Washington office and adapted them to meet the local requirements of his job.

Having determined to use existing engineering and contracting firms, it became necessary to formulate a contract which would short-cut the peace-time red tape and procedure of the War Department and make it possible to get immediate action and quick results, at the same time relieving the contractor of many of the hazards growing out of the war which he would incur under a lump sum form of contract, but still protecting to the fullest possible degree the Government's interests. A number of well-established methods were considered and discarded; the lump sum contract, the lump sum contract with cost plus for changes and additions, the agency form of contract, and the unit price form of contract were all open to serious objection. They were not flexible enough to permit the changes in plan, the increase in size and scope of the work and the modifications in the type of construction, which it was known, would have to be made to meet the new and ever-changing requirements developed by experience at the front.

In no case when a construction project was begun, was the completed project clearly delineated or its final requirements known. I have in mind one job, which, when begun, was planned as a small project, costing a quarter of a million dollars, and which, before it was completed, was expanded a hundred fold and cost twenty-five million dollars. This is an extreme case, but the principle held good throughout all the work which the Construction Division did, and both its engineering and administrative organization, as well as its construction forces, had to be organized and made flexible enough to immediately adjust themselves to any change in requirements which new developments in the science of warfare might impose.

Twice the cantonment plans had to be materially altered after construction was well under way. First, because the regimental units and company quarters were laid out to fit the American Army organization as it existed previous to the war. General Pershing did not arrive in Europe until June 15, 1917. He immediately found that the experience of both the British and French Armies had demonstrated that a company of 250 men was a more convenient size for trench warfare than the smaller 150-man company

of the American Army, and the plans for the barracks buildings and regimental areas were changed accordingly. Again experience demonstrated that the health of the troops might be put in jeopardy by overcrowding and for that reason the Surgeon General revised his plans and required that at least 500 cubic feet of air space be provided in barracks and quarters for each man housed therein. To provide for such contingencies as these the contract for construction had to be of the utmost flexibility. The main point was to get started and get started immediately with the possibility of developing the details of the project as its requirements became more and more definite.

Due to the urgent necessity for speedy completion of the work, there was no time for drawing up detailed plans and specifications had it been practicable to make them. The job had to be finished in less time than it ordinarily took to prepare plans. The creation of a field organization, the drawing of plans, the procurement of the materials, the engineering work at the site and the actual building construction all had to go hand in hand and all had to be begun immediately. The only form of contract which would permit this method of procedure was the one adopted. It is generally called, in the War Department, the Emergency Form of contract. A more descriptive name, though perhaps a cumbersome one, is "the cost of the work with a sliding scale of percentage, limited by a fixed fee." Its critics have, since the Armistice, tried to discredit it by calling it the "cost plus 10 per cent. contract." This is indeed a misnomer for only on the smallest jobs, totalling less than $100,000 in cost, and prior to October, 1917, was a 10 per cent. fee paid. (After this date a fee of 7 per cent. was the maximum fee paid.) On the greater portion of the work not more than 4 per cent. or 5 per cent. was paid the contractor.

Briefly stated, the contractor was reimbursed for the actual cost of the project, plus a percentage fee for the services of his organization. This fee grew less and less as the cost of the job increased, until the maximum limit of $250,000 was reached, after which no more fee was paid, regardless of the size of the job. The plan worked well. Where a job was estimated at the time the work was started to cost $100,000 the contractor might receive a maximum fee of $10,000; if it cost less than the estimate, he received 10 per cent. of the actual expense; if it cost more than

the $100,000 estimate, he received only the $10,000; on work estimated to cost $250,000 a fee of 8 per cent. was the maximum allowed and so on down, until the percentage fee on a three and a half million dollar contract was 6 per cent. At the time each job was authorized an upset fee was fixed, based on the estimated cost, beyond which the contractor would not be paid. The contract definitely provided that in no case should the total fee paid on any job, regardless of its size, exceed $250,000. In this way a contractor might receive a $250,000 fee on a job costing $5,000,000, but he would receive no more than $250,000 if his job cost twenty million dollars.

After the contractor had paid out of this fee the cost of his main office and the salaries and expenses of the members of his firm engaged on the work, his surety bonds and the interest on the capital required to finance his job, only a small part of his gross fee remained as net profit. On the sixteen National Army cantonments the gross fee paid to the contractor ran between 2 and 3 per cent. of the cost of the work. On some of the larger jobs, because of the $250,000 maximum limit, it was not more than 1 per cent., whereas had these projects been let on a lump sum basis, under the hazard of war-time construction, the contractor would have been obliged to add from 10 to 25 per cent. to his estimate of cost to cover his profit and his contingencies. A criticism of this form of contract generally implies a lack of appreciation of the conditions under which this work had to be done. The fixing of an upset fee on each job, regardless of its size, beyond which the fee paid to the contractor could not go, had a tendency to check extravagancies or any desire to prolong the job. It was to the decided interest of the contractor to finish his work in the shortest possible time, to do it as cheaply as he possibly could and thereby establish his reputation for good work and thus win favorable consideration for additional work.

This contract has stood successfully against every assault and there has never been a successful refutation of the form used as protecting the interest of the Government and allowing the utmost flexibility and freedom of action. It must not be confused with an ordinary cost-plus-a-percentage contract, under which the more the job costs the more the contractor receives, for it was far from such.

The Secretary of War appointed a committee, including the

Presidents of the National Engineering Societies, the Chamber of Commerce of the United States, the Construction Employees' Association and the American Federation of Labor, to review every form of contract which might be used for war work, and compare it with the Emergency Form, to determine whether or not any other kind of instrument would permit the Government to carry forward its construction program to better advantage. They reported briefly as follows: "No reasonable objection can be pointed out by anyone possessing a full understanding of its equitable operations and practice, and finally this scheme possesses one qualification which must commend it to all thinking men: it permits starting actual work weeks and even months before the details are completely worked out and delineated and permits the Government to push the job at any speed it may elect, changing at will its plan and scope and paying only what the work actually costs, plus a fee which is so reasonable as to be above the reach of fair-minded criticism."

The organization plan of the Construction Division is a simple one. There is a central organization in Washington, which lays down the fundamental requirements for each project, procures the authority and funds for its construction and follows the work through from its inception to completion. The details of the job are handled in the field at the site of the work. They are directly under an officer called the Constructing Quartermaster, who is responsible to the Government for the satisfactory completion of his job and for the proper disbursement of funds. He is the commanding officer during construction and all other agents, both engineer and contractor, report to him. His organization is built up to meet the requirements of the particular project under his charge and is a miniature of the main organization in Washington, having its engineering, materials, administrative, accounting and labor departments. In cases where difficulties are experienced or where advice is needed, he takes the matter up direct with a Supervisor in Washington, who is the point of contact between the Washington Office and the field. This Supervisor has a group of jobs under his direction and sees to it that his several Constructing Quartermasters in the field are kept in daily touch with the material and labor situation, furnished plans, and that materials purchased directly by the Washington organization have clearance and are shipped to the jobs and that

all legal and auditing matters are in accord with Government practice. The Supervisor in turn reports to a Section Chief, who is generally responsible for the work of some particular bureau, such as hospitals for the Surgeon General's Office, ordnance plants, or aircraft work. These Section Chiefs and their groups of jobs make up the Building Division and report to the Officers in Charge thereof.

The Engineering, Contracts, Administrative, Accounting, Requirements and Procurement Divisions act as service sections for the Building and Utilities Divisions, furnishing to the field forces expert technical data which the requirements of the job demand. The work of these several service sections is fairly well indicated by their names. The Engineering Division is responsible for all engineering matters from the survey of sites to complete and detailed plans for buildings and utilities, water supply, sewage disposal plants, heating, lighting, camp sanitation and the like. The Contracts Division prepares the contracts and interprets them, and acts in a similar capacity to a general counsel of a large business organization. The Administrative Division is charged with the employment of civilians, adjusts all wages, the settlement of labor disputes and the clerical work in the Washington Office. The Accounting Division attends to the money matters, including the auditing and checking of the expenses of the jobs. The Requirements Division presents the requests for authority to the Secretary of War, through the Director of Operations, and secures the necessary funds. The Procurement Division keeps in touch with the markets of the country and mobilizes and arranges for the transportation of the huge quantities of building materials required for the many projects under the jurisdiction of the main office. The Building Division is responsible for the conduct of the actual operations in the field and during the War was the manufacturing department of the business, its finished project being camps, hospitals, ordnance plants, etc., with the other departments assisting it in its stupendous task. The Utilities Division maintains and operates the project after its completion. The present organization differs but little in its plan from that which was laid down at the beginning of the war and the basic principle then established has controlled its activities since its inception.

The Construction Division, during the period of its war activi-

ties, was the largest construction organization in the history of the world and the largest employer of labor. In addition to its commissioned and clerical personnel, its working force numbered 427,000 laborers, more than twice as great an army as that which fought at Gettysburg on both the Union and Confederate sides, and more than four times the number of our Regular Army at the time of the declaration of war. This construction force had to be housed and fed during the construction period and this in itself was no simple problem, for many of the sites chosen for the camps were located on remote and virgin fields without a single facility for the accommodation of the labor which must build them. The outstanding feature of this work was the magnitude of the operation combined with the speed of its accomplishment. The individual buildings which made up the project were in themselves neither intricate of design nor difficult of construction, but the task of assembling them into a complete whole within the short time available so that they might be ready to serve their purpose was one of the things that made victory possible. Upon the continuity of supply of men and munitions the destinies of the overseas forces were absolutely dependent. Once a project was conceived it took its place in a definite schedule and it had to be completed in accordance with that schedule, or else all of the arrangements of the War Department based upon its being ready to perform its function at a given time would have been thrown into confusion by the failure of one step in the process. Can you imagine the resulting confusion had the operation of the draft been delayed because these camps were not ready to receive the men, or what might have happened had the newly made soldiers not been able to sail for France because of the lack of embarkation facilities? The Construction Division was one Government agency which delivered the goods on time.

Previous to the War the several bureaus of the War Department did their construction work independent and ofttimes in competition with each other. After the camps and cantonments were completed and the advisability of concentrating construction under a single head had been so clearly proven, the Secretary of War delegated to the Construction Division all the construction work required in this country. Each bureau made known its requirements, plans and estimates were then prepared by the Construction Division, authority for the expenditure of the neces-

sary funds was secured from the Secretary of War, a contractor was recommended by the Council of National Defense and approved by this Division and the construction work immediately started. Full authority for every detail of the work was placed upon the Construction Division and it was held accountable only for results.

In order that you may appreciate some of the phases of the work a few words may be in order as to how the building of the National Army camps was carried out. There were 16 of these projects, whose location was selected by a special Board of Regular Army officers in May and June of 1917. The last site was not approved until July 6th. Upon each of these sites it was required to build a camp capable of housing 40,000 men and accommodating 14,000 animals. Each one of these camps had to be a self-contained community with every modern facility for the comfort and health of the men who would be trained there. Barracks, mess halls, lavatories, administration buildings, officers' quarters, storehouses, refrigerating plants and laundries had to be built, water and sewer systems installed, roads constructed and railroad tracks laid, and lighting and heating provided. Each camp was in itself a veritable modern city, costing from 8 to 12 million dollars, which had to be created from the ground up within the short space of three months. If you can picture in your mind what it would mean to have to provide in that short space of time housing accommodations for all the people in Philadelphia, while New York, Baltimore and Pittsburgh were all equally busy on similar rush work and therefore fighting for the available labor and materials and freight cars which your job required, you will have some idea of the size of the task and the difficulties involved.

The fundamental engineering principle laid down by the Washington Office for adaptation to the conditions in the field were based on both Army and Municipal experience in this country modified by information received from our Allies. The Town Planner and Landscape Architect, together with the Fire Prevention Experts, prepared typical layout plans, indicating the amount of space required for the various buildings and the arrangement of the regimental areas. The varying topography at the several sites made it necessary to adjust these typical layouts to fit the ground in the field. To give an idea of the size and character of a complete camp, Camp Grant at Rockford, Illinois, may be

taken as a fair illustration. This cost approximately $11,000,000 and has a capacity of 43,000 men and 12,000 animals housed in 1600 buildings. The water supply system includes 6 wells, 38 miles of pipe and a reservoir of 550,000 gallons capacity. The electric lighting system required 1450 miles of copper wire, 1200 poles and 35,000 incandescent lamps. About 50,000,000 feet of lumber was required for its construction, which was erected at the rate of 500,000 board feet per day. The Division Hospital has a capacity of 1000 beds. Camp Lewis, at American Lake, Washington, is one of the most beautifully located of all the cantonments and is even larger than Camp Grant. It cost, in 1917, about $215 per man to provide complete housing accommodation in the National Army Camp and about $88 per man in the National Guard tent camps.

The water supply for the camps presented another serious problem. It was determined that 50 gallons per capita per day should be allowed for each man in camp and 15 gallons for each animal. This is about 80 per cent. more water than was supplied to the British, French, Canadian, Belgium or German camps. The primary requisite, of course, was to provide a water of unquestioned purity and where there was any possible danger from pollution to filter and sterilize it before distribution. In some cases existing water works systems in the nearby cities were available but even in such cases the strictest sanitary control was exercised over the plant and many betterments and extensions made. In some cases these extensions were financed by the Government, the municipality reimbursing the Government for the expenditure in free water. Where water was purchased the average cost was approximately 8 cents per 1000 gallons. In many locations independent plants were built including the most modern pumping and filtration apparatus. In all, some 275 different water supply installations were made, involving construction of 1100 miles of pipe from six to thirty inches in diameter, 700 miles of service pipe, ¾ inch to 2 inches in diameter, with a combined pumping capacity of 650,000,000 gallons per day; the reservoir capacity in tanks was 67,000,000 gallons, while impounding reservoirs capable of holding 3,000,000,000 gallons were constructed; filter plants were built having a daily capacity of 40,000,000 gallons and more than 4,000,000 troops and 2,000,000 civilians were supplied with water. Up to date there has not been a single case of

typhoid fever or other water-borne disease attributed to the impurity of any water supply, designed, operated or controlled by the Construction Division, which in itself is one of the outstanding facts in the history of this war.

Owing to the shortage in iron and the need for this metal for munitions, cast-iron and steel pipe was not available for the camp water systems except in limited quantities. Wood-stave pipe of Canadian white pine and California redwood was used, resulting in a large saving, both in money and time of laying. California redwood tanks of 200,000 gallons' capacity were largely used for the storage of water, their cost was much less than either steel or concrete, and the time and labor required for their erection only a fraction of that necessary for steel or concrete reservoirs.

Hand in hand with the need for providing a safe water supply was the necessity for disposal of sewage and other wastes in the most sanitary possible manner. With populations ranging from five to sixty thousand men and with a density of population in many cases much higher than found in cities, it was necessary to take every possible sanitary precaution. Standard designs and general specifications for the construction of sewer systems and sewage treatment plants and for garbage incinerators and can-washing equipment were prepared in the Washington Office and turned over to the Supervising Engineer on the job for adaptation and execution.

The standard tanks for sewage treatment were the multiple compartment horizontal flow type, provided with cross baffles so as to facilitate sedimentation and to permit the withdrawal of sludge. The bottoms were pyramidal and where the effluent was discharged into a large stream, no other treatment than dosing the effluent with chlorine was required. In some cases sprinkling filters and secondary sedimentation tanks were installed. In designing the sewage treatment plants an allowance was made for 60 gallons per capita. In hospitals 150 gallons per bed, and 60 gallons for each attendant was assumed as the basis for design. More than 1000 miles of sewer pipe were laid, over 100 sewage disposal plants were built, with a combined capacity of 20,000,000 gallons. The total area of the sprinkling filters constructed is over 500,000 square feet. The cost of the tanks

complete, with filters, at each of the 40,000 men camps was about $200,000, or $5 per capita.

It early developed that the amount of grease in the kitchen waste was far in excess of that encountered in ordinary municipal sewage. To relieve the sewage of this excessive grease load and prevent its interference with the operation of the disposal plants, a special type of grease trap was developed by means of which it was possible to recover about 95 per cent. of the grease contents in the sewage. It was found that about 13 pounds per capita per year of grease valuable for commercial use could be obtained from the wastes from the kitchens. Much of the camp waste was of commercial value. Garbage stations were erected and the waste material carefully classified was generally separated into garbage, fats, grease, bones, bottles, tin cans, paper and manure and so much as was of value sold under contract to Waste Disposal Companies. Special incinerators were designed and built by the Construction Division to destroy the wastes which had no market value. In some cases piggeries were established and the camp garbage thus profitably converted into fresh meat for the Army. As a result the Government received over a million dollars a year income from what would otherwise have been a total loss.

Many of the ideas developed in connection with the sanitation and waste disposal work were original in character and will be a permanent contribution toward the science of sanitary engineering.

The necessity for providing roads to carry the heaviest possible traffic, after some experiment, led to the choice of concrete as the most suitable type of pavement, but other types were used, such as brick, gravel, macadam and bitulithic, where the materials could be quickly procured.

It may not be out of place to once more call attention to the tremendous decrease in the proportion of deaths from disease brought about by the intelligent supervision and exercise of stringent sanitary regulations during the present war. As a proof of the efficiency of such measures as pure water and proper sewage facilities, drainage, mosquito control, comfortable housing and adequate hospitals, it is interesting to compare the figures during this war with those of our previous wars: In the Mexican War the deaths from disease amounted to 110 per thousand men; in

the Civil War, this was reduced to 65 per thousand men; in the Spanish-American War, 26 per thousand, and in the Russian-Japanese War the deaths among the Japanese troops which at that time represented the highest attainment in sanitary practice was 20 per thousand.

In July and August, 1918, when the camps and cantonments were in full operation, the death-rate from disease was 2.8 men per thousand, which is less than half of the death-rate for men of military age in civilian life. The rate from the beginning of the war up to the outbreak of the influenza epidemic was less than five per thousand men.

One feature of the work of the Construction Division that contributed largely toward this remarkable record was the provision all over the United States of ample hospital accommodations. Plans were prepared in conjunction with the office of the Surgeon General, not only for the hospitals in each of the Divisional Camps, but for special hospitals at many other places, including those for the treatment of tuberculosis, shell shock, for reconstruction work and other special requirements growing out of service in the theatre of operations. Altogether accommodations were provided for 121,000 patients, 12,000 nurses, 34,000 enlisted men and 4000 doctors. Many of these hospitals were built on heretofore unoccupied ground and required in addition to the buildings the installation of the necessary sewers, water and electric lighting systems, roads, and railroads. The camp hospital buildings were generally of one-story wooden construction connected by closed corridors so that patients might be readily wheeled in roller chairs from one building to another. These corridors were cut off from the main buildings by fire walls to prevent the spread of possible fires. Provision was made for every appliance of the modern hospital. X-ray laboratories, bacteriological laboratories, hydrotherapeutic wards and the most complete operating rooms and special laboratories for research work were installed. As the war progressed, the hospital plans were modified and terra-cotta block and stucco on metal lathe substituted for wood, and the buildings made two and three stories in height, thus bringing the units closer together and facilitating administration. At a number of the Regular Army Posts departmental hospitals were established, using the original post hospital as a nucleus and remodelling other buildings to meet the requirements and at certain

places throughout the country general hospitals, some of them containing from 2000 to 4000 beds, were constructed. Such commercial buildings as the old Siegal-Cooper store and the Grand Central Palace in New York were converted and made into large reception hospitals for the sick and wounded soldiers returning from overseas. At Ashville, N. C., and Denver, Colorado, special hospitals were constructed for the treatment of tuberculosis and other lung troubles.

The German drive in the spring of 1918, with its resulting large number of casualties, made it evident that a decided increase in the hospital accommodations would have to be provided immediately. There was no time to build new construction and in consequence a number of private buildings, such as museums, industrial plants, the Ford automobile factories and properties of like nature were taken over and converted by the Construction Division into reasonably satisfactory hospitals. In all, the Construction Division provided through new construction, purchase or remodelling a total of 294 hospitals, costing approximately $128,000,000. These ranged in cost from $750 per bed up to $2000, depending upon the isolation of the site and the character of construction.

Practically all of the buildings in the camps were of frame construction and therefore very inflammable. The fire hazard in the camps and hospitals was one which caused a great deal of concern until the effectiveness of fire prevention measures and inspections was so clearly demonstrated. A number of fires have started, but in only three cases has the fire spread beyond the buildings of its origin. The records for the year of 1918 show that the per capita loss by fire throughout the United States was $2.70, whereas the total per capita loss at the various Construction Division activities for the year ending June 30, 1918, was only 67 cents.

Of all of the construction projects, those built for the Ordnance Department are of the greatest interest, embracing as they do many new problems of construction and manufacture, plant layout, and shop arrangement. There were sixty of these projects costing a total of $175,000,000. One of the largest is the Proving Ground at Aberdeen, Maryland. Here are accommodations for 8000 men, a plant 165 feet wide and 500 feet long for assembling gun carriages and mounts for artillery and the

largest machine shop in the United States. The reservation contains 35,000 acres of land with facilities for every conceivable test, which may be desired of the many different types of guns and munitions developed during the war. There is also a bombing field where airplanes may practice aero bombing and 4000 acres are given over to the manufacture and testing of gas shells. This latter area is known as Edgewood Arsenal and its facilities cost approximately $30,000,000. There are quarters for 10,000 men and a gas-filling plant with a capacity of 120,000 loaded shells per day. Here mustard gas, phosgene, caustic soda, picric acid and other weapons of chemical warfare were produced on a large scale.

Explosives from their very nature must be stored by themselves and far away as possible from thickly settled sections, and at the same time this storage must be convenient to railroads and docks so that the contents of these magazines could be delivered to ocean-going vessels without unnecessary handling. The difficulty of finding such sites which were suitable for such construction within reasonable distance of deep water and rail facilities was apparent at the outset. Five of these projects were located along the Atlantic Coast, one at Metuchen, N. J., Pedricktown, Del., Pig Point, Va., Curtis Bay, Md., and Charleston, S. C. The Raritan Arsenal, which is at Metuchen, N. J., is the largest of these projects. This reservation comprises 2200 acres of salt marsh, which to prevent its submersion at high tide, had to be protected with a dike around the entire reservation. The soil itself was such that every structure erected had to be supported on piles. An Ordnance School was also located at this point with accommodations for 10,000 men. Fifty miles of railroad were required and a dock of 2000 feet in length with warehouses and other facilities were provided at a cost of about $14,000,000.

Bag-loading plants were another development made necessary by the War. Guns up to, and including 4.7 calibre, used ammunition in which the explosive is loaded in a metal cartridge case, similar in appearance to small arms ammunition, but guns of larger size used what is known as unfixed ammunition, that is, the powder is packed in silk bags of the diameter of the gun and after the projectile is placed in the bore of the gun a bag or number of bags, depending on the size of the gun, are loaded into the breech to form the propelling charge. The filling of these

bags must be done with the utmost accuracy, after the explosive itself has been carefully blended in order that no variation in the propellant force of the charge may occur. Three of these plants were constructed, one at Woodbury, N. J., one at Tullytown, Pa., and one at Seven Pines, Va. Because of the character of the work and the danger incident to the operation of the plant, these had to be as isolated as possible. So that complete quarters for the employees, many of whom were women, had to be built to provide for the operating personnel. These plants involved many new problems of engineering details and yet they were completed within three months' time.

Practically all of the shipping facilities required for the War were under the direction of the Shipping Board; the Construction Division, however, built and placed in operation 276 barges and lighters for use in handling supplies in connection with the Newark Terminal and for the loading and transportation of munitions from the Pig Point and Curtis Bay Storage Depots to the outward-bound ships.

At the beginning of the war, construction pertaining to the Air Service was under the jurisdiction of the Signal Corps, but after October, 1917, the Construction Division began taking over the construction work which was then in progress and after the early part of 1918 did all of this work. Flying fields were established in many parts of the country and housing provided for their personnel. Special buildings were constructed for housing of dirigible balloons and there is now in course of construction at Langley Field, Virginia, the largest dirigible hangar in the world. The R-34, which made the Trans-Atlantic flight, is 78 feet in diameter. This new hangar will accommodate a dirigible 100 feet in diameter and still leave space in the clear for a 16-foot car. Balloon schools were also constructed at Lee Hall, Virginia, and Arcadia, California, and used for the training of aerial observers. In the design of the dirigible hangars which are 168 feet high and 680 feet long, the problem of the door design is a difficult one. These doors are 70 feet in height and 40 feet wide. Their structural makeup and the method of opening them when they are in place, is one of considerable interest to a structural engineer, as well as the large amount of bracing required to withstand the heavy pressure of the wind against such a large surface.

For the Motor Transport Corps, maintenance and repair shops were constructed for assembling tanks, tracks and trucks used in connection with the Mobile Artillery, as well as for the ordinary passenger automobile. At Baltimore, Atlanta, and San Antonio, large projects for this purpose included enormous shops and garages and training schools. The buildings are fitted with the finest types of machine tools, cranes and other equipment and compare favorably with the most up-to-date automobile factories.

While the activities of the Construction Division have been confined to this side of the Atlantic, a notable exception may be mentioned in the case of the refrigerating and cold storage plants, designed, purchased, and shipped to France. Immediately upon the assemblage of the necessary materials for these plants, the Construction Division also organized the personnel for their operation. When the United States entered the war, there was available for the use of the American soldiers in France a storage capacity of only 750 tons of beef. This was later increased to 4000 tons capacity. During the same time the Construction Division provided in this country a capacity for 24,000 tons of beef. Owing to the distance that this beef had to be transported, a sharp freezer plant had to be provided where chilled beef could be hard frozen at a temperature of 15 degrees above zero in order to make it easy and safe for transportation. To meet this emergency, the Construction Division erected at Chicago the largest sharp freezer plant in the world. It is the most modern type of concrete and brick construction, insulated throughout with cork. It has a daily freezing capacity of 1400 tons, equivalent to 5000 animals, and a storage capacity of 14,000 tons of frozen beef.

Refrigerating and ice-making plants were designed and constructed at many of the camps and hospitals, but these were generally small in size, being designed to produce from 50 to 200 tons of ice per day, adequate for the army population of their particular locality.

Among the largest projects built by the Construction Division are the huge terminals at Boston, Brooklyn, Norfolk, Charleston and New Orleans. In them was concentrated the vast store of materials required by the overseas forces. Here these supplies were collected and loaded on ships. Tributary to these embarka-

tion terminals or Army Supply Bases were interior Storage Depots located at important railroad junction points and convenient to the great manufacturing centres of the country. Depots of this character were established at Philadelphia, New Cumberland, Pa., Schenectady, New York, Columbus, Ohio, St. Louis, Chicago, Jeffersonville, Ind., Pittsburgh and Baltimore. They provide a total storage space of 12,000,000 square feet.

These Army Supply Bases may be described as a combination railroad terminal and storehouse for the protection of merchandise and its transshipment to ocean-going vessels. The Boston Base is eight stories in height and is 128 feet wide and 1628 feet long. It has a storage space of 2,750,000 square feet. This building is paralleled by a wharf shed of the same length, two storied in height, while at the outer end of the 4000-foot pier, carrying these buildings, are two upper sheds, each 924 feet, by three stories. The terminal yard includes 30 miles of railroad track, extending to and through the various buildings, as well as along the sides of the dock. This huge project was built in five months and cost 25 million dollars. At Brooklyn there are two 8-story concrete warehouses, each 980 feet in length, one being 200 and the other 300 feet in width. These buildings contain four million square feet of storage space. Serving them are three double-deck piers, each 150 feet in width and 1300 feet long, and an upper pier 60 feet wide and 1300 feet long. The storage tracks will accommodate 1300 freight cars and the docks permit twelve 800-ton ships to be loaded at one time. With the mechanical equipment it is possible to load a vessel in 24 hours. This project was completed in approximately one years' time, and cost $28,000,000.

The Norfolk Base contains two million square feet of storage space, a mile of dock and terminal tracks for freight cars. This project required the reclamation of 217 acres of mud flats, the building of concrete pile bulkhead, and the filling in with material removed from the harbor to give the required depth to accommodate deep draught vessels. Here a cantonment was erected for a regiment of stevedores and a battalion of guards, including a 120-bed hospital. This project was completed in about 12 months' time and cost $25,000,000.

The Army Bases at Newark and at Charleston, S. C., are the one-story type and similar to Norfolk, while that at New Orleans was of reinforced concrete and comparable with the Brooklyn and

Boston projects. These Army Supply Bases and the Interior Storage Depots have a combined storage capacity of 27,502,300 square feet. With an additional 2,176,000 square feet of storage capacity and open sheds, an area equivalent to a building seventy feet wide and eighty-one miles long, the docking space is capable of accommodating 65 ships at one time. Eight hundred and forty-four miles of railroad track and 1061 miles of concrete road serve these projects.

This, in brief, is an outline of the scope of the work done by the Construction Division. It is a remarkable fact to my mind that such an organization could be suddenly created and built up in a period of 18 months into the greatest construction outfit of all time, and that, by the welding together of peace-trained engineering and building organizations into a military unit with a single purpose, it could undertake and carry to successful completion a building program on a vaster scale than was ever before conceived in the mind of man. Out of its success there is engendered a new feeling of respect in the Army for the capacity of the civilian scientist, engineer and constructor and his value as a military asset, a feeling that he may be depended upon in any future emergency, to quickly divert his talents to warfare as effectively as he follows his normal, peaceful pursuits, for he has proven his worth and established his war value. His contact with the Army has also given him a new viewpoint which enabled him to better sense the military problem of the country and to contribute understandingly towards its solution.

Much of the work which the Construction Division did was of necessity a part of the waste of war, in the same sense that the powder shot on the battle front was waste, and it has no permanent value as a peace-time asset, and yet there are many of its projects which have already become an important part of the economic fabric of our nation. The Army Supply Bases at Brooklyn and Boston, and at Norfolk, Charleston and New Orleans represent the finest port terminal facilities in the world. In connection with an American Merchant Marine, they will become as useful for peace as they were in time of war, and they were designed and built with this thought in view.

Against the huge sums spent by the War Department, there is the offset of such improvements as these terminals. In many other localities there have been provided new roads, new manufac-

turing developments, enlargement of electric, steam and gas plants, provision for better sewage disposal and adequate water supply, rehabilitation of both steam and electric railroads, the establishment of steamship and railroad terminals, the drainage of malarial areas and reconstruction of buildings and communities to improve living conditions, all of which the demands of war forced into existence, and which now remain as a vast asset to the country. Thus have our "shields been beaten into plowshares and our swords into pruning hooks."

To few men have fortuitous circumstances brought such an experience as has come to me as Chief of the Construction Division. I have felt a thrill in directing the efforts of this great creative body of men. I have seen the engineer, the highly specialized technical expert, the contractor, the auditor, the engineer, the clerk and the laborer rise at their country's call and for the time being throw off the hampering jealousies and restrictions of their normal life and accomplish the impossible; and the credit for this achievement rests largely upon men, such as you, who make up the membership of Franklin Institute, the American Society of Civil Engineers and the other national technical associations, and who more and more are dominating the future course of this great nation.

Electrolytic Chromium. (Advance sheets of a paper by GEO. J. SARGENT, Res. Chemist, from the 37th general meeting of the Amer. Electrochemical Society, Boston, April 8–10.)—Brief allusion is made to the history of the deposition of chromium, including some unpublished work by Skillman of Cornell University. Details are given of the various mixtures of chromic sulphate and chromic acid showing that the yield of metal is greatly increased by the presence of chromic sulphate. Comparisons of results with rotating and stationary cathodes and of the differing temperatures and strength of solution are tabulated. Very good deposits of chromium were obtained in some of the experiments, low temperatures yielding fair ampere-hour efficiency at comparatively low current density. The chromium deposit is very resistant to corrosion by ordinary influences, for which reason the author concludes that such plating has important commercial possibilities.

H. L.

Electrical Supply in Small Dwellings. (*Electrician,* Feb. 13, 1920.)—In Great Britain Messrs. W. T. Henley's Telegraph Works Company is making a special point of lighting workmen's houses by electricity. In one installation the tenant is charged 28s. per annum for a six-room house with only one lamp in a room. The cost of wiring is much reduced by a twin metal sheath system and by using series systems in some and parallel systems in others. The cost of wiring in 1914 was 7s. 6d. per light and the cost of maintenance has proved to be small. G. F. S.

Testing Roads for Heavy Travel. (*Weekly News Letter, U. S. Department of Agriculture,* vol. vii, No. 32, p. 8.)—State highway departments are vitally interested in the successful outcome of comprehensive experiments and tests now being made by the Bureau of Public Roads of the United States Department of Agriculture. One State engineer recently declared that millions of dollars in his State are involved in the proper design of road surfaces, which make up one of the problems being investigated by the Federal engineers.

The coming into general use of the heavy motor truck has practically revolutionized the science of road-building. Big new problems came when loads weighing 10 to 15 tons took the place of vehicles that placed a weight one-fourth as much or less. The roads built ten years ago were constructed before this fact could be realized—which is one of the reasons why many "permanent" roads have proved to be impermanent.

One of the testing experiments being made by the Federal Bureau involves the use of a 49-section roadway in the Arlington farm, owned by the Department of Agriculture. Each section was built from a different type of material, or with a different method of construction. The same use is given to each section, so that eventually the type of construction best suited to heavy traffic will prove itself. R.

Research Grant.—The American Pharmaceutical Association has available a sum amounting to about $450, which will be expended after October 1, 1920, for the encouragement of research. This amount, either in full or fractions, will be awarded in such manner as will in the judgment of the A.Ph.A. Research Committee produce the greatest good to American pharmaceutical research.

Investigators desiring financial aid in their work will communicate before May 1st with H. V. Arny, Chairman A.Ph.A. Research Committee, 115 West 68th Street, New York, giving their past record and outlining the particular line of work for which the grant is desired.

The committee will give each application its careful attention and will make recommendations to the American Pharmaceutical Association at its meeting in Washington, May 3d to 8th, 1920, when the award or awards will be made.

THE CHARGE ON THE ELECTRON AND THE VALUE OF PLANCK'S CONSTANT h.*

BY

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LEWIS AND ADAMS (*Phys. Rev.* (2), 3, 92, (1914) from a theory of ultimate rational units, *i.e.* by a kind of dimensional reasoning, have derived the following relation between Planck's constant h and the electron charge e.

$$h = \frac{e^2}{c} \times 32\pi^3 \sqrt[3]{\frac{\pi^2}{15}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where c is the velocity of light (2.9986×10^{10} cm. per sec.). If we take for e the value 4.774×10^{-10} e.s. units as determined by Millikan (*Phys. Rev.* (2), 2, 143, 1913) this gives

$$h = 6.560 \times 10^{-27} \text{ erg seconds.}$$

In a recent paper R. T. Birge (*Phys. Rev.* 14, 361, 1919) has calculated h in seven different ways and obtains as the most probable value

$$h = 6.5543 \times 10^{-27}.$$

Every method of determining h, however, involves the use of e so that any error in this quantity produces a corresponding uncertainty in h. Sommerfeld in his recent book on atomic structure (*Atombau und Spectrallinien,* Nov., 1919) has given a new relation between h and e in terms of the Rydberg constants obtained with hydrogen and helium. From Bohr's theory, taking into account the masses of the nuclei of the atoms, and by comparing the spectra of hydrogen and helium, he is able to calculate the value of e/m with very great accuracy (here m is the mass of the electron). He obtains

$$e/m = 1.7686 \times 10^7 \text{ e. m. units,}$$

$$\text{or } c \times 1.7686 \times 10^7 \text{ e. s. units.}$$

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* Communicated by the Author.

Besides being based upon the spectroscopic wave lengths, this value involves a knowledge of the ratio of the atomic weights of helium and hydrogen (4.000 : 1.008). The relative error in e/m, however, is only about one-third as great as that in the ratio of the atomic weights. Sommerfeld has furthermore derived the relations

$$e = \frac{\alpha^3 c^2}{4\pi N_\infty (e/m)} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where

$$\alpha = \frac{2\pi e^2}{hc} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Here N_∞ is the wave number corresponding to the Rydberg constant for an infinitely heavy nucleus. It has the value

$$N_\infty = 109737.11 \text{ cm.}^{-1} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

These equations together with the Lewis and Adams relation enable us to calculate a new value of the electron charge e. Combining Equations 1 and 3 we find

$$\alpha = \frac{1}{16\pi^2} \sqrt[3]{\frac{\pi^2}{15}} = 0.0072798 \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

Substituting this together with the values of N_∞ and e/m in Equation 2 gives

$$e = 4.745 \times 10^{-10} \text{ e.s. units} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

while this value substituted in (1) gives

$$h = 6.481 \times 10^{-27} \text{ erg seconds.}$$

This value of e is about 0.6 per cent. lower than that given by Millikan, who estimates the accuracy of his result as 0.2 per cent. However, Millikan's determination has never been checked by any independent method of comparable accuracy, so it seems possible that a constant error of the above magnitude might have affected his results. The value of h given by Equation 7 is 1.2 per cent. lower than the value calculated by Birge but this results merely from the different value for e. The following table gives the values of h calculated from the seven sets of data used by Birge: first, using Millikan's value $e = 4.774$; and second, using the value $e = 4.745$.

Determinations of h.

Method	Dependence on e.	$e=4.774$	$e=4.745$
Stefan-Boltzmann Constant	$e^{4/3}$	6.551	6.497
Wien Constant c_2	e	6.557	6.517
Bohr-Sommerfeld theory, Equations 2 and 3	$e^{5/3}$	6.548	6.481
Einstein's photo-electric equation	e	6.578	6.538
Quantum relation for X-rays	$e^{4/3}$	6.555	6.501
Lewis and Adams theory	e^2	6.560	6.481
Quantum relation for ionization potentials	e	6.579	6.539
	Average	6.555	6.507

The values of h calculated from $e=4.745$ are consistently smaller than those based on Millikan's value, but they agree among themselves within the probable experimental error. In any case the results do not warrant the conclusion that the Lewis and Adams or the Bohr-Sommerfeld theories are not rigorous. Unless one of these theories is incorrect or incomplete, however, the values of e and h represented by Equations 6 and 7 should have a much higher accuracy than any of the other experimental determinations given in the above table. Under these conditions it seems desirable that new determinations of the electron charge should be made, especially if new methods can be developed.

An Experimental Determination of the Inertia of a Sphere Moving in a Fluid. GILBERT COOK. (*Philosophical Magazine,* March, 1920.)—Sir G. G. Stokes showed that a solid body moving in a fluid of infinite extent has its inertia apparently increased by the effect of fluid pressure. This effect became of interest in war time in connection with the theory of oscillating mines. A spherical mine-case 38.2 inches in diameter, ballasted so that its weight in water was only one pound, was allowed to fall freely through the water in a tank 15 feet in diameter and 30 feet deep. The motion was automatically recorded and the velocity and acceleration were calculated. When the acceleration is plotted against the square of the velocity the points lie close to a straight line. The faster the mine sinks the less is its acceleration. When the apparent inertia was computed it came out equal to 1.46 times the ordinary mass of the case.

G. F. S.

Quotations from the Diary of Samuel Pepys on the Weather. (*Quart. Jour. Royal Meteorol. Soc.*, January, 1920.)—It is now recognized that loud sounds are surrounded by zones in which they are inaudible. Beyond these come other areas in which the sounds may once more be heard. Under date of June 2, 1666, Pepys records that he went "into the Parke, and there we could hear the guns from the fleete most plainly." Two days later, "so walking through the Parke we saw hundreds of people listening at the Gravell-pits; and to and again in the Parke to hear the guns, and I saw a letter dated last night, from Strowd, Governor of Dover Castle, which says that the Prince (Rupert) come thither the night before with his fleete, but that the guns which we writ that we heard, it is only a mistake for thunder; and so far as to yesterday it is a miraculous thing that we all Friday, and Saturday and yesterday, did hear everywhere most plainly the guns go off, and yet at Deale and Dover to last night they did not hear one word of a fight, nor think they heard one gun. This makes room for a great dispute in philosophy, how we should hear and they not, the same wind that brought it to us being the same that should bring it to them: but so it is." These observations are in agreement with recent experience during the war.

G. F. S.

The Effect of High Temperature, Humidity and Wind on the Human Body. (*Quart. Jour. Royal Meteorol. Soc.*, January, 1920.)—Men die in the desert from the effects of the simoom, a strong, hot and very dry wind. The explanation offered is this: "Because, therefore, the bodily gain of heat by convection from the air increases as the strength of the wind increases, and because the human body cannot perspire above a certain maximum rate, it is easy to see that to each air temperature above blood heat there must, theoretically, at least, correspond a certain critical value of the wind velocity, which, if exceeded, must produce a net gain of heat to the body. Also, the lower the air temperature the higher will be the critical wind velocity at which conditions become unlivable. Under actual atmospheric conditions this limit appears never to be exceeded except in an exceptionally hot and dry wind."

G. F. S.

Wireless Network for the British Empire. (*Electrician*, March 12, 1920.)—Marconi's Wireless Telegraph Company has proposed to the Imperial Wireless Sub-committee to establish a network connecting Great Britain with all other parts of the Empire, including ships at sea between latitudes 60 N. and 50 S. Twenty-six main-trunk stations would be built, five of which would be in Great Britain. The staff, some thousands in number, would all be British subjects. The white members would belong to reserve military or naval units. G. F. S.

THEORETICAL MAXIMUM PRESSURE DEVELOPED IN OWN VOLUME BY THIRTEEN MILITARY EXPLOSIVES.*

BY

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During the World War, the Explosives Experiment Station of the Bureau of Mines carried out at the request of, and in coöperation with, the Ordnance Department of the U. S. Army, physical tests of the different explosives used for shell-loading, bombs and similar purposes. Among the different tests carried out, one of the most important, if not the most important test, is the Theoretical Maximum Pressure Developed in Own Volume, as this test shows directly the power available in the explosive for demolition purposes and shell fragmentation, and correlated with the rate of detonation of the explosive, is of great value in selecting the explosive for any desired purpose.

The maximum pressure of an explosive in its own volume is the pressure an explosive would exert if exploded or detonated in a space that it fills completely, all the heat set free by the chemical reactions that take place being retained by the products of the explosion. A part of this heat is absorbed through the confining surface. By varying the confining surface, its heat-absorbing effect is measured and combining this measurement with the recorded pressure, the total pressure is calculated.

The Bichel pressure gauges are used for this purpose. The volume of the gauges is 15 litres and the cooling surfaces used are (*A*) 3914 square centimetres, (*B*) 6555 square centimetres, and (*C*) 7624 square centimetres. An indicator gauge similar to a steam indicator gauge on the Bichel pressure gauge records the pressure on a revolving drum.

The pressure in own volume is computed by the formula

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$M = \frac{VPS}{W}$ in which V represents the volume of the Bichel gauge, which is always 15,000 cubic centimetres; S, the specific gravity of the material and W the weight in grams of the charge used in the test. P is determined by means of the formula $P = 1.911A + 0.5B - 1.411C$ in which P represents the pressure with elimination of cooling surface and probable error. This formula expresses the geometrical relation obtained by plotting the average pressure developed in two tests agreeing within 5 per cent. for each cooling surface against the area of the cooling surface, the line drawn through the three points being extended to the ordinate or zero cooling surface. By plotting the pressures against the cooling surfaces the effect of the cooling surfaces is determined and eliminated.

In making the tests, 200 grams of the explosive was loaded in an 8-oz. glass bottle and a No. 8 electric detonator embedded full length in the charge. A layer of dry plaster-of-Paris was then placed on top of the explosive and detonator, after which the bottle was sealed with wet plaster-of-Paris, which was allowed to set before making the test. The prepared charge was then exploded in the Bichel pressure gage evacuated to 50 millimetres pressure.

Samples $M-2302$[1] of 80/20 amatol (acutally 85/15 amatol), $M-2303$ of 60/40 sodatol, $M-2325$ of trinitroxylene and $M-2344$ of trinitronaphthalene would not detonate completely under the above conditions. The method of preparing the charge was then modified by inserting in the explosive charge a 24-gram booster of tetryl ($M-2326$) packed in a test tube. The No. 8 electric detonator was embedded in the booster charge. The bottle was then sealed as above, and exploded in the Bichel gauge evacuated to 50 millimetres pressure.

Sample $M-2307$ of ammonium picrate would not detonate completely in vacuum with a booster either of tetryl or picric acid. Acordingly, the test was carried out at atmospheric pressure in the Bichel gauge, using a picric acid booster ($M-2308$).

The tests were usually made in duplicate within 5 per cent. But on certain explosives, where irregular results were obtained,

[1] Record number on office key-card, Bureau of Mines.

in spite of every precaution the average of all tests was taken as giving the more accurate result.

In calculating the results of those explosives where a booster was used the effect of the booster was eliminated from the value for P (pressure eliminating the effect of cooling surface), as follows: $P = P_1 - P_2$ where P_1 = pressure (of explosive and booster) after elimination of surface influence P_2 = pressure of booster after elimination of surface influence (9.287 kilograms per square centimetre for 24 grams tetryl, 8.642 kilograms per square centimetre for 24 grams picric acid).

As density has a very important effect on the theoretical maximum pressure, and as these explosives may be used at widely varying densities, the results of each explosive are given in a table showing the theoretical maximum pressure for densities of loading varying over the limits which may be used.

The details of the tests are as follows:

M–2302 of 80/20 amatol (actually 85/15 amatol).
24 gram booster of tetryl (*M*–2326).
Indicator spring 0.32 millimetre = 1 kilogram per square centimetre.

Date 1919	Test No.	Charge	Specific gravity	Height of curve	Pressure per square centimetre	Cooling surface	Average pressure per square centimetre
		Grams		*Millimetres*	*Kilograms*		*Kilograms*
March 14...	*P*–1721	200	1.02	36.50[b]	91.25	*A*	
March 14...	*P*–1723	200	1.02	30.25	94.53	*A*	
March 14...	*P*–1722	200	1.02	30.75	96.09	*A*	93.96
March 14...	*PP*–2301	200	1.02	28.75	89.84[a]	*B*	
March 14...	*PP*–2302	200	1.02	26.00	81.25	*B*	
March 14...	*PP*–2303	200	1.02	26.25	82.03	*B*	81.64
March 14...	*PP*–2304	200	1.02	27.75	86.72	*C*	
March 14...	*PP*–2305	200	1.02	24.00	75.00[c]	*C*	
March 17...	*PP*–2306	200	1.02	26.50	82.81	*C*	84.77

[a] Not included in average. No apparent reason for high result.
[b] Indicator spring 0.40 millimetres = 1 kilogram per square centimetre.
[c] Not included in average. No apparent reason for low result.

$P = (1.911A + 0.5B - 1.411C) - 9.287 = 91.48$ kilograms per square centimetre.

TABLE I.

Theoretical Maximum Pressure in Own Volume of Sample M–2302 of 80/20 Amatol (actually 85/15 Amatol) at Densities of Loading Varying from 1.30 to 1.60.

Density	Kilograms per square centimetre	Pounds per square inch
1.30	8919	126860
1.35	9262	131340
1.40	9605	136610
1.45	9948	141490
1.50	10292	146390
1.55	10635	151270
1.60	10978	156150

M–2303 of 60/40 sodatol.
24 gram booster of tetryl (*M*–2326).
Indicator spring 0.32 millimetre = 1 kilogram per square centimetre.

Date 1919	Test No.	Charge	Specific gravity	Height of curve	Pressure per square centimetre	Cooling surface	Average pressure per square centimetre
		Grams		*Millimetres*	*Kilograms*		*Kilograms*
March 19...	*P*–1726	200	1.21	28.25[a]	70.62	*A*	
March 19...	*P*–1727	200	1.21	27.50[a]	68.75	*A*	69.68
March 18...	*PP*–2309	200	1.21	20.00	62.50	*B*	
March 18...	*PP*–2310	200	1.21	21.50	67.19	*B*	
March 18...	*PP*–2311	200	1.21	19.50	60.94	*B*	
March 21...	*PP*–2320	200	1.21	27.50[a]	68.75	*B*	
March 21...	*PP*–2321	200	1.21	21.00	65.62	*B*	65.00
March 17...	*PP*–2307	200	1.21	21.50	67.19	*C*	
March 18...	*PP*–2308	200	1.21	22.00	68.75	*C*	
March 25...	*PP*–2324	200	1.21	20.00	62.50	*C*	
March 21...	*PP*–2322	200	1.21	21.00	65.62	*C*	
March 25...	*PP*–2325	200	1.21	19.75	61.72	*C*	65.16

[a] Indicator spring 0.40 millimetres = 1 kilogram per square centimetre.

$P = (1.911A + 0.5B - 1.411C) - 9.287 = 73.72$ kilograms per square centimetre.

TABLE II.

Theoretical Maximum Pressure in Own Volume of Sample M–2303 of 60/40 Sodatol at Densities of Loading Varying from 1.50 to 1.80.

Density	Kilograms per square centimetre	Pounds per square inch
1.50	8294	117970
1.55	8570	121890
1.60	8846	125820
1.65	9123	129760
1.70	9399	133680
1.75	9676	137620
1.80	9952	141550

Sample *M*–2304 of 50/50 amatol.
Indicator spring 0.40 millimetre = 1 kilogram per square centimetre.

Date 1918	Test No.	Charge	Specific gravity	Height of curve	Pressure per square centimetre	Cooling surface	Average pressure per square centimetre
		Grams		*Millimetres*	*Kilograms*		*Kilograms*
Nov. 11....	*P*–1674[a]	200	1.30	23.50	73.44	*A*	
Nov. 22....	*P*–1675	200	1.30	29.25	73.12	*A*	73.28
Nov. 27....	*PP*–2196	200	1.30	29.50	73.75	*B*	
	2197	200	1.30	27.00	67.50	*B*	
	2198	200	1.30	28.75	71.88	*B*	
	2199	200	1.30	28.25	70.62	*B*	70.90
	2200	200	1.30	26.75	66.88	*C*	
	2201	200	1.30	28.50	71.25	*C*	
	2202	200	1.30	28.75	71.88	*C*	70.00

[a] Indicator spring 0.32=1 kilogram per square centimetre.

$P = 1.911A + 0.5B - 1.411C = 76.72$ kilograms per square centimetre.

TABLE III.

Theoretical Maximum Pressure in Own Volume of Sample M–2304 of 50/50 Amatol at Densities of Loading Varying from 1.30 to 1.60.

Density	Kilograms per square centimetre	Pounds per square inch
1.30	7480	106390
1.35	7768	110490
1.40	8056	114580
1.45	8343	118660
1.50	8631	122760
1.55	8919	126860
1.60	9207	130960

Sample *M*–2305 of TNA.
Indicator spring 0.40 millimetre = 1 kilogram per square centimetre.

Date 1919	Test No.	Charge	Specific gravity	Height of curve	Pressure per square centimetre	Cooling surface	Average pressure per square centimetre
		Grams		*Millimetres*	*Kilograms*		*Kilograms*
Feb. 26.....	*P*–1704	200	0.87	31.00	77.50	*A*	
Feb. 26.....	*P*–1705	200	.87	29.50	73.75	*A*	75.63
Feb. 21.....	*PP*–2274	200	.87	27.50	68.75	*B*	
	2272	200	.87	26.50	66.25[a]	*B*	
	2273	200	.87	28.50	71.25	*B*	70.00
	2275	200	.87	28.00	70.00	*C*	
	2276	200	.87	27.25	68.12	*C*	69.06

[a] Omitted from average. No apparent reason for low result.

$P = 1.911A + 0.5B - 1.411C = 82.09$ kilograms per square centimetre.

TABLE IV.

Theoretical Maximum Pressure of Sample M–2305 of TNA at Densities of Loading Varying from 0.80 to 1.60.

Density	Kilograms per square centimetre	Pounds per square inch
.80	4925	70050
.85	5233	74430
.90	5541	78810
.95	5849	83090
1.00	6159	87570
1.05	6465	91950
1.10	6772	96320
1.15	7080	100700
1.20	7388	105080
1.25	7696	109460
1.30	8004	113840
1.35	8312	118220
1.40	8619	122590
1.45	8927	126970
1.50	9235	131350
1.55	9534	135730
1.60	9851	140110

Sample *M*–2307 of ammonium picrate.
Fired at atmospheric pressure in gauge.
24 gram booster of picric acid (*M*–2308–*A*).
Indicator spring 0.40 millimetre = 1 kilogram per square centimetre.

Date 1919	Test No.	Charge	Specific gravity	Height of curve	Pressure per square centimetre	Cooling surface	Average pressure per square centimetre
		Grams		*Millimetres*	*Kilograms*		*Kilograms*
March 20...	*P*–1730	200	0.82	31.25	78.12	*A*	
March 20...	*P*–1731	200	.82	29.00	72.50[a]	*A*	
March 21...	*P*–1732	200	.82	32.00	80.00	*A*	79.06
March 21...	*PP*–2316	200	.82	30.75	76.88[b]	*B*	
March 21...	*PP*–2317	200	.82	28.50	71.25	*B*	
March 21...	*PP*–2318	200	.82	29.00	72.50	*B*	71.88
March 21...	*PP*–2319	200	.82	28.50	71.25	*C*	
March 23...	*PP*–2323	200	.82	27.50	68.75	*C*	70.00

[a] No apparent reason for low result.
[b] No apparent reason for high result.

$P = (1.911A + 0.5B - 1.411C) - 8.642 = 79.61$ kilograms per square centimetre.

TABLE V.

Theoretical Maximum Pressure of Sample M–2307 of Ammonium Picrate at Densities of Loading Varying from 0.80 *to* 1.60.

Density	Kilograms per square centimetre	Pounds per square inch
.80	4777	67940
.85	5075	72180
.90	5374	76440
.95	5672	80670
1.00	5971	84930
1.05	6269	89170
1.10	6568	93420
1.15	6866	97660
1.20	7165	101910
1.25	7463	106150
1.30	7762	110400
1.35	8061	114650
1.40	8359	118890
1.45	8658	123140
1.50	8956	127380
1.55	9255	131640
1.60	9553	135870

Sample *M*–2308–*A* of picric acid.
Indicator spring 0.60 millimetre = 1 kilogram per square centimetre.

Date	Test No.	Charge	Specific gravity	Height of curve	Pressure per square centimetre	Cooling surface	Average pressure per square centimetre
		Grams		*Millimetres*	*Kilograms*		*Kilograms*
Dec. 14, 1918	*P*–1692	200	0.94	25.25[a]	63.12	*A*	
Feb. 10, 1919	*P*–1698	200	.94	39.25	65.42	*A*	64.27
Dec. 13, 1918	*PP*–2235	200	.94	35.75	59.58	*B*	
Feb. 12, 1919	*PP*–2261	200	.94	36.50	60.83	*B*	
Dec. 13, 1918	*PP*–2234	200	.94	34.00	56.67	*B*	59.03
Dec. 13, 1918	*PP*–2229	200	.94	21.75[a]	54.38	*C*	
Dec. 13, 1918	*PP*–2230	200	.94	37.25	62.08	*C*	
Dec. 13, 1918	*PP*–2232	200	.94	25.25	58.75	*C*	
Dec. 13, 1918	*PP*–2233	200	.94	31.50	52.50	*C*	56.93

[a] Indicator spring 0.40 millimetres = 1 kilogram per square centimetre.

$$P = 1.911A + 0.5B - 1.411C = 72.02 \text{ kilograms per square centimetre.}$$

TABLE VI.

Theoretical Maximum Pressure of Sample M–2308—A of Picric Acid at Densities of Loading Varying from 0.80 *to* 1.60.

Density	Kilograms per square centimetre	Pounds per square inch
.80	4321	61460
.85	4591	65300
.90	4861	69140
.95	5131	72980
1.00	5402	76830
1.05	5672	80670
1.10	5942	84510
1.15	6212	88350
1.20	6482	92190
1.25	6752	96040
1.30	7022	99880
1.35	7292	103720
1.40	7562	107560
1.45	7832	111400
1.50	8102	115240
1.55	8372	119080
1.60	8642	122920

Sample *M*–2320 of grade I TNT.
Indicator spring 0.40 millimetre = 1 kilogram per square centimetre.

Date 1918	Test No.	Charge	Specific gravity	Height of curve	Pressure per square centimetre	Cooling surface	Average pressure per square centimetre
		Grams		*Millimetres*	*Kilograms*		*Kilograms*
Nov. 21....	*P*–1673	200	0.91	20.50[a]	64.06	*A*	
Dec. 5.....	*P*–1685	200	.91	38.00[b]	63.33	*A*	
Dec. 5.....	*P*–1686	200	.91	37.25[b]	62.08	*A*	63.16
Nov. 29....	*PP*–2207	200	.91	25.75	64.38	*B*	
Nov. 29....	*PP*–2208	200	.91	24.50	61.25	*B*	62.82
Nov. 29....	*PP*–2205	200	.91	24.75	61.88	*C*	
Nov. 29....	*PP*–2206	200	.91	24.50	61.25	*C*	61.56

[a] Indicator spring 0.32 millimetres = 1 kilogram per square centimetre.
[b] Indicator spring 0.60 millimetres = 1 kilogram per square centimetre.

$$P = 1.911A + 0.5B - 1.411C = 65.58 \text{ kilograms per square centimetre.}$$

TABLE VII.

Theoretical Maximum Pressure of Sample M–2320 of Grade I TNT at Densities of Loading Varying from 0.80 to 1.60.

Density	Kilograms per square centimetre	Pounds per square inch
.80	3935	55970
.85	4181	59470
.90	4427	62970
.95	4673	66470
1.00	4919	69960
1.05	5164	73450
1.10	5410	76950
1.15	5656	80450
1.20	5902	83950
1.25	6148	87440
1.30	6394	90940
1.35	6640	94440
1.40	6886	97940
1.45	7132	101440
1.50	7378	104940
1.55	7624	108440
1.60	7870	111940

Sample *M*–2321 of grade II TNT.
Indicator spring 0.60 millimetre = 1 kilogram per square centimetre.

Date 1918	Test No.	Charge	Specific gravity	Height of curve	Pressure per square centimetre	Cooling surface	Average pressure per square centimetre
		Grams		*Millimetres*	*Kilograms*		*Kilograms*
Dec. 3.....	*P*–1680	200	0.91	38.00	63.33	*A*	
	P–1682	200	.91	39.75	66.25	*A*	64.79
	PP–2209	200	.91	35.75	59.59	*B*	
	PP–2210	200	.91	35.50	59.17	*B*	59.38
	PP–2211	200	.91	35.25	58.75	*C*	
	PP–2212	200	.91	35.50	59.17	*C*	58.96

$P = 1.911A + 0.5B - 1.411C = 70.31$ kilograms per square centimetre.

TABLE VIII.

Theoretical Maximum Pressure of Sample M–2321 of Grade II TNT at Densities of Loading Varying from 0.80 to 1.60.

Density	Kilograms per square centimetre	Pounds per square inch
.80	4219	60010
.85	4482	63750
.90	4746	67500
.95	5010	71260
1.00	5273	75000
1.05	5537	78750
1.10	5801	82510
1.15	6064	86250
1.20	6328	90000
1.25	6592	93760
1.30	6855	97500
1.35	7119	100250
1.40	7383	105010
1.45	7646	108750
1.50	7910	112510
1.55	8174	116260
1.60	8437	120000

Sample *M*–2328 of grade III TNT.
Indicator spring 0.60 millimetre = 1 kilogram per square centimetre.

Date 1918	Test No.	Charge	Specific gravity	Height of curve	Pressure per square centimetre	Cooling surface	Average pressure per square centimetre
		Grams		*Millimetres*	*Kilograms*		*Kilograms*
Dec. 4.....	*P*–1683	200	0.91	38.00	63.33	*A*	
	P–1684	200	.91	36.50	60.83	*A*	62.08
	PP–2213	200	.91	38.25	63.75	*B*	
	PP–2215	200	.91	37.25	62.08	*B*	
Dec. 5.....	*PP*–2219	200	.91	34.25	57.08	*B*	
Dec. 5.....	*PP*–2220	200	.91	35.25	58.75	*B*	60.42
Dec. 5.....	*PP*–2216	200	.91	35.75	59.58	*C*	
Dec. 5.....	*PP*–2218	200	.91	35.25	58.75	*C*	59.16

$P = 1.911A + 0.5B - 1.411C = 65.37$ kilograms per square centimetre.

TABLE IX.

Theoretical Maximum Pressure of Sample M–2328 of Grade III TNT at Densities of Loading Varying from 0.80 *to* 1.60.

Density	Kilograms per square centimetre	Pounds per square inch
.80	3922	55780
.85	4167	59270
.90	4412	62750
.95	4658	66250
1.00	4903	69740
1.05	5148	73220
1.10	5393	76710
1.15	5638	80190
1.20	5883	83680
1.25	6128	87160
1.30	6374	90660
1.35	6619	94140
1.40	6864	97630
1.45	7109	101110
1.50	7354	104600
1.55	7599	108080
1.60	7844	111570

Sample *M*–2325 of trinitroxylene.
24 gram booster of tetryl (*M*–2326).
Indicator spring 0.40 millimetre = 1 kilogram per square centimetre.

Date 1919	Test No.	Charge	Specific gravity	Height of curve	Pressure per square centimetre	Cooling surface	Average pressure per square centimetre
		Grams		*Millimetres*	*Kilograms*		*Kilograms*
Mar. 13....	*P*–1719	200	0.82	23.50	58.75	*A*	
	P–1720	200	.82	22.75	56.88	*A*	57.82
	PP–2299	200	.82	22.00	55.00	*B*	
	PP–2300	200	.82	22.25	55.62	*B*	55.31
	PP–2297	200	.82	21.25	53.12	*C*	
	PP–2298	200	.82	21.50	53.75	*C*	53.44

$P = (1.911A + 0.5B - 1.411C) - 9.287 = 53.46$ kilograms per square centimetre.

TABLE X.

Theoretical Maximum Pressure of Sample M–2325 of Trinitroxylene at Densities of Loading Varying from 0.80 to 1.60.

Density	Kilograms per square centimetre	Pounds per square inch
.80	3208	45630
.85	3408	48470
.90	3609	51330
.95	3809	54180
1.00	4010	57040
1.05	4210	59880
1.10	4410	62720
1.15	4611	65580
1.20	4811	68430
1.25	5012	71290
1.30	5212	74130
1.35	5413	76990
1.40	5613	79830
1.45	5814	82690
1.50	6014	85540
1.55	6215	88390
1.60	6415	91240

Sample *M*–2326 of tetryl.
Indicator spring 0.40 millimetre = 1 kilogram per square centimetre.

Date 1919	Test No.	Charge	Specific gravity	Height of curve	Pressure per square centimetre	Cooling surface	Average pressure per square centimetre
		Grams		*Millimetres*	*Kilograms*		*Kilograms*
Feb. 26.....	*P*–1706	200	0.99	28.75	71.88	*A*	
Feb. 26.....	*P*–1707	200	.99	26.75	66.88	*A*	
Feb. 27.....	*P*–1708	200	.99	31.25	78.12	*A*	
Feb. 27.....	*P*–1709	200	.99	27.50	68.75	*A*	71.41
Feb. 21.....	*PP*–2269	200	.99	28.50	71.25	*B*	
Feb. 21.....	*PP*–2271	200	.99	27.50	68.75	*B*	70.00
Feb. 20.....	*PP*–2266	200	.99	27.00	67.50	*C*	
Feb. 20.....	*PP*–2267	200	.99	26.50	66.25	*C*	
Feb. 21.....	*PP*–2270	200	.99	26.50	66.25	*C*	66.67

$P = 1.911A + 0.5B - 1.411C = 77.39$ kilograms per square centimetre.

TABLE XI.

Theoretical Maximum Pressure of Sample M–2326 of Tetryl at Densities of Loading Varying from 0.80 to 1.60.

Density	Kilograms per square centimetre	Pounds per square inch
.80	4643	66040
.85	4934	70180
.90	5224	74300
.95	5514	78430
1.00	5804	82550
1.05	6094	86680
1.10	6385	90820
1.15	6675	94940
1.20	6965	99060
1.25	7255	103190
1.30	7546	107330
1.35	7836	111450
1.40	8126	115580
1.45	8416	119700
1.50	8706	123830
1.55	9196	127960
1.60	9486	132090

Sample *M*–2336 of hexanitrodiphenylamine.
Indicator spring 0.40 millimetre = 1 kilogram per square centimetre.

Date 1919	Test No.	Charge	Specific gravity	Height of curve	Pressure per square centimetre	Cooling surface	Average pressure per square centimetre
		Grams		*Millimetres*	*Kilograms*		*Kilograms*
Feb. 14.....	*P*–1702	200	0.81	28.75	71.88	*A*	
	P–1703	200	.81	28.50	71.25	*A*	71.57
	PP–2262	200	.81	23.75	59.38	*B*	
Feb. 18.....	*PP*–2263	200	.81	24.50	61.25	*B*	60.32
	PP–2264	200	.81	23.50	58.75	*C*	
	PP–2265	200	.81	24.25	60.62	*C*	59.69

$P = 1.911A + 0.5B - 1.411C = 82.71$ kilograms per square centimetre.

TABLE XII.

Theoretical Maximum Pressure of Sample M–2336 of Hexanitrodiphenylamine at Densities of Loading Varying from 0.80 to 160.

Density	Kilograms per square centimetre	Pounds per square inch
.80	4963	70590
.85	5273	75000
.90	5583	79410
.95	5893	83820
1.00	6203	88230
1.05	6513	92640
1.10	6824	97060
1.15	7134	101470
1.20	7444	105880
1.25	7754	110290
1.30	8064	114700
1.35	8374	119110
1.40	8685	123530
1.45	8995	127940
1.50	9305	132350
1.55	9615	136760
1.60	9925	141170

Sample *M*–2344 of trinitronaphthalene.
24 gram booster of tetryl (*M*–2326).
Indicator spring 0.40 millimetre = 1 kilogram per square centimetre.

Date 1919	Test No.	Charge	Specific gravity	Height of curve	Pressure per square centimetre	Cooling surface	Average pressure per square centimetre
		Grams		*Millimetres*	*Kilograms*		*Kilograms*
March 10...	*P*–1716	200	0.99	22.25[a]	69.53[b]	*A*	
March 11...	*P*–1717	200	.99	25.75	64.38	*A*	
	P–1718	200	.99	26.00	65.00	*A*	64.69
	PP–2292	200	.99	23.00	57.50[c]	*B*	
	PP–2293	200	.99	24.50	61.25	*B*	
	PP–2294	200	.99	25.25	63.12	*B*	62.19
March 12...	*PP*–2295	200	.99	25.25	63.12	*C*	
	PP–2296	200	.99	24.00	60.00	*C*	61.56

[a] Indicator spring 0.32 millimetres = 1 kilogram per square centimetre.
[b] No apparent reason for high result.
[c] No apparent reason for low result.

$P = 1.911A + 0.5B - 1.411C - 9.287 = 58.57$ kilograms per square centimetre.

TABLE XIII.

Theoretical Maximum Pressure of Sample M–2344 of Trinitronaphthalene at Densities of Loading Varying from 0.80 *to* 1.60.

Density	Kilograms per square centimetre	Pounds per square inch
.80	3514	49980
.85	3734	53110
.90	3953	56220
.95	4173	59350
1.00	4393	62480
1.05	4612	65600
1.10	4832	68730
1.15	5052	71860
1.20	5271	74970
1.25	5491	78100
1.30	5711	81230
1.35	5930	84340
1.40	6150	87470
1.45	6369	90590
1.50	6589	93720
1.55	6809	96850
1.60	7029	99980

TABLE XIV.

Recapitulation of Theoretical Maximum Pressure in Own Volume in Pounds per Square Inch.

Density	80/20 Amatol *M*-2302	60/40 Sodatol *M*-2303	50/50 Amatol *M*-2304	TNA *M*-2305	Ammonium picrate *M*-2307	Picric Acid *M*-2308	TNT Grade I *M*-2320	TNT Grade II *M*-2321	TNT Grade III *M*-2328	Trinitroxylene *M*-2325	Tetryl *M*-2326	Hexanitrodiphenylamine *M*-2336	T. N. N. *M*-2344
0.80	.....	.....	.....	70070	67940	61460	55970	60010	55780	45630	66040	70590	49980
.85	.....	.....	.....	74430	72180	65300	59470	63750	59270	48470	70180	75000	53110
.90	.....	.....	.....	78810	76440	69140	62970	67500	62750	51320	74300	79410	56220
.95	.....	.....	.....	83090	80670	72980	66470	71260	66250	54180	78430	83820	59350
1.00	.....	.....	.....	87570	84930	76830	69960	75000	69740	57040	82550	88230	62480
1.05	.....	.....	.....	91950	89770	80670	73450	78750	73220	59880	86680	92640	65600
1.10	.....	.....	.....	96320	93420	84510	76950	82510	76710	62720	90820	97060	68730
1.15	.....	.....	.....	100700	97660	88350	80450	86250	80190	65580	94940	101470	71860
1.20	.....	.....	.....	105080	101910	92190	83950	90000	83680	68430	99060	105880	74970
1.25	.....	.....	.....	109460	106150	96040	87440	93760	87160	71290	103190	110290	78100
1.30	126860	.....	106390	113840	110400	99880	90940	97500	90660	74130	107330	114700	81230
1.35	131340	.....	110490	118220	114650	103720	94440	101250	94140	76990	111450	119110	84340
1.40	136610	.....	114580	122590	118890	107560	97940	105010	97630	79830	115580	123530	87470
1.45	141490	.....	118660	126970	123140	111400	101440	108750	101110	82690	119700	127940	90590
1.50	146390	117970	122760	131350	127380	115240	104940	112510	104600	85540	123830	132350	93720
1.55	151270	121890	126860	135730	131640	119080	108440	116260	108080	88390	127960	136760	96850
1.60	156150	125820	130960	140110	135870	122920	111940	120000	111570	91240	132090	141170	99980
1.65	.....	129760	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1.70	.....	133680	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1.75	.....	137620	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1.80	.....	141550	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

TABLE XV.

Recapitulation of Theoretical Maximum Pressure in Own Volume in Kilograms per Square Centimetre.

Density	80/20 Amatol *M*-2302	60/40 Sodatol *M*-2303	50/50 Amatol *M*-2304	TNA *M*-2305	Ammonium picrate *M*-2307	Picric Acid *M*-2308	TNT Grade I *M*-2320	TNT Grade II *M*-2321	TNT Grade III *M*-2328	Trinitroxylene *M*-2325	Tetryl *M*-2326	Hexanitrodiphenylamine *M*-2336	T. N. N. *M*-2344
0.80	.....	....	....	4925	4777	4321	3935	4219	3922	3208	4643	4963	3514
.85	.....	....	....	5233	5075	4591	4181	4482	4167	3408	4934	5273	3734
.90	.....	....	....	5541	5374	4861	4427	4746	4412	3609	5224	5583	3953
.95	.....	....	....	5849	5672	5131	4673	5010	4658	3809	5514	5893	4173
1.00	.....	....	....	6157	5971	5402	4919	5273	4903	4010	5804	6203	4393
1.05	.....	....	....	6465	6269	5672	5164	5537	5148	4210	6094	6513	4612
1.10	.....	....	....	6772	6568	5942	5410	5801	5393	4410	6385	6824	4832
1.15	.....	....	....	7080	6866	6212	5656	6064	5638	4611	6675	7134	5052
1.20	.....	....	....	7388	7165	6482	5902	6328	5883	4811	6965	7444	5271
1.25	.....	....	....	7696	7463	6752	6148	6592	6128	5012	7255	7754	5491
1.30	8919	....	7480	8004	7762	7022	6394	6855	6374	5212	7546	8064	5711
1.35	9262	....	7768	8312	8061	7292	6640	7119	6619	5413	7836	8374	5930
1.40	9605	....	8056	8619	8359	7562	6886	7383	6864	5613	8126	8685	6150
1.45	9948	....	8343	8927	8658	7832	7132	7646	7109	5814	8416	8995	6369
1.50	10292	8294	8631	9235	8956	8102	7378	7910	7354	6014	8706	9305	6589
1.55	10635	8570	8919	9543	9255	8372	7624	8174	7599	6215	9196	9615	6809
1.60	10978	8846	9207	9851	9553	8642	7870	8437	7844	6415	9486	9925	7029
1.65	.....	9123	....	....	....	....	....	....	....	....	....	....	....
1.70	.....	9399	....	....	....	....	....	....	....	....	....	....	....
1.75	.....	9676	....	....	....	....	....	....	....	....	....	....	....
1.80	.....	9952	....	....	....	....	....	....	....	....	....	....	....

No comparison is made between the strength of these explosives as shown by the theoretical maximum pressure as the different explosives are not all used at the same density. However, Tables XIV and XV furnish the data so that an explosive at one density may be compared with any other explosive at a selected density.

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S. P. Howell, Explosives Engineer, Bureau of Mines, and Lieutenant W. V. Evans, Ordnance Department, U. S. Army, for helpful suggestions in carrying out the work; J. E. Tiffany, W. J. Montgomery and A. B. Coates, Assistant Explosives Engineers of the Bureau of Mines, and Sargent J. Pfromme, Corporal C. E. Gault, and Privates B. Lindh and F. Wanner, for their aid in making the tests.

The December, 1919, Number of the Transactions of the Faraday Society is devoted to a discussion of "The Present Position of the Theory of Ionization," to which Arrhenius contributes a paper on the evidence in favor of the theory. N. R. Dhar discusses Snethlage's hypothesis of the condition of dissolved electrolytes and finds it wanting. The fifteen papers, with the accompanying discussion, form a useful contribution to the study of Arrhenius' theory.

G. F. S.

Oil and Gas Prospects in East-central New Mexico. (*U. S. Geological Survey, Press Bulletin* No. 441.)—The geologic structure of parts of New Mexico has been under investigation during the last four years by N. H. Darton, a geologist of the United States Geological Survey, Department of the Interior, who has discovered in the beds of rock many domes and arches that may be reservoirs of oil or gas if these substances are present in the regions examined. These flexed beds are parts of geologic formations that produce oil in Wyoming, Oklahoma, Kansas, and Texas, but in New Mexico little evidence of the presence of oil and gas in them has yet been found. A small amount of oil at Dayton and a few seeps and some traces of oil reported in water wells at several other places are the only favorable indications so far reported. Only a few deep wells have been bored in New Mexico, however, and these are in places where the structure is not favorable for the occurrence of oil or gas, or the wells were not drilled deep enough to make them satisfactory tests. Much of the geologic guidance used in locating the wells drilled has come from incompetent "experts," the presence of one "dome," for ex-

ample, having been deduced from haphazard readings of dip taken on layers of cross-bedded sandstone. One probably hopeless project is a deep hole in the middle of Tularosa Desert, where there are no rock outcrops to indicate the structure. In some of the hectic literature written to promote the sale of oil stock the chief geologist of the United States Geological Survey is falsely quoted as authority for the statement that New Mexico would develop one of the biggest oil fields on this continent.

Localities of Domes and Arches.—The general structure of east-central New Mexico is that of an eastward-dipping monocline, but there are local reversals of dip due to domes and arches, or anticlines, some of which are rather prominent. Only a few of the areas where these structural features appear to merit the attention of the geologist and driller can be mentioned here. In Guadalupe County, for example, the apex of one of the most clearly marked domes is in the west-central part of T. 11 N., R. 19 E. The uplifted beds, which are 2500 feet thick, are of Permian and Pennsylvanian age, and the Pennsylvanian beds lie on granite at a vertical depth of 2000 feet or more. On Pintada Creek, in the centre of T. 8 N., R. 19 E., there is a smaller dome involving the same strata, and a slightly less pronounced dome is indicated in the same canyon a few miles above Pintada post office. There are several broad, low arches in the strata in the northeast corner of this county and in adjoining parts of San Miguel, the next county to the north. In Quay County a broad, low anticline in the "red beds" passes a short distance east of Tucumcari and extends for some distance north and south of the Rock Island Railroad. In De Baca County the strata dip nearly due east in general, but a few local reversals of dip suggest that minor domes or arches may be found when a detailed survey is made. Lincoln County is traversed by a broad anticline that lies east of the Sierra Blanca structural basin and passes near Lincoln. In the western part of Lincoln County there are several domes that appear to be favorable for the storage of oil, although there is no visible evidence that they contain oil. They are in T. 6 S., R. 9 E., in the northeastern part of T. 9 S., R. 8 E., and in the centre of T. 5 S., R. 12 E. In the eastern part of Socorro County, three miles northeast of the Carthage coal mines, there is a notable elongated dome which brings up the Mesaverde coal measures; at Prairie Springs there is a dome in the limestones of Permian age; and in the centre of T. 2 S., R. 4 E., there is a dome in the Abo red beds. The plunging anticline at the north end of the Oscura Mountain uplift is also in the eastern part of this county.

Wells Should be Sunk Deep.—All test wells sunk in this region should be carried entirely through the sedimentary series, which in the domes and anticlines mentioned is from 2000 to 3000 feet thick and at intervals from top to bottom contains coarse sands, some of which may be oil burning.

ON THE RESISTANCE OF DUCTILE MATERIALS TO COMBINED STRESSES IN TWO OR THREE DIRECTIONS PERPENDICULAR TO ONE ANOTHER.*

BY

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If two structural steel plates are pulled, the one by a simple tension in one direction only, the other by equal tensions in two directions perpendicular to one another, then the question arises: in which case, if the unit stresses are the same, is there the greater safety? For example, if 14,000 lbs. per. sq. in. is a safe working stress in the case of a simple tension, what would be the safe working stress in the case of equal tensions in the two perpendicular directions? Different answers to this question and to the general question of the resistance of materials to combined stresses are given by several different theories or assumptions, which in the course of time have been proposed as bases of design.

Rankine's theory, the maximum stress theory, states that the tendency to failure is measured by the greatest tensile or compressive unit stress; that is, with 14,000 lbs. per sq. in. as a working stress in simple tension, the same working unit stress would be used in biaxial tension. *Saint-Venant's maximum strain theory* measures the tendency to rupture by the greatest unit-elongation or unit-shortening, as computed by the formulas applying to deformations below the elastic limit (see the equations given later). On account of the lateral contraction effect, measured by the so-called Poisson's ratio of lateral contraction, which for steel is equal to about 0.3, the unit-elongation caused by equal tensions in two directions will be about 30 per cent. less than (or 0.7 of) the greatest unit-elongation caused by the same stress applied as a simple tension; or, by Saint-Venant's theory the working stress in the case of biaxial equal tensions, corresponding to 14,000 lbs. per sq. in. in simple tension, should be 14,000/.7 = 20,000 lbs. per sq. in. A third theory, the *maximum shear theory*, originally proposed by Coulomb (1773), and adopted by

* Communicated by the Author.

Guest (1900) and others, states that failure occurs when the greatest shearing unit stress exceeds a certain limit. In the case of biaxial tension, the maximum shearing unit stress occurs in planes making angles of 45° with the plane of the tensions, and it is equal to one-half the greatest tensile unit stress (see more complete formulas given below). Or, in the example considered, a tensile stress of 14,000 lbs. per sq. in. would give the same shear, 7000 lbs. per sq. in., whether it is applied as a simple or as a biaxial tension. That is, a working stress of 14,000 lbs. per sq. in. in simple tension would lead to the same working stress for the case of biaxial tensions. Other theories have also been proposed; one, to which particular attention will be given in this discussion, was indicated by A. J. Becker[1] as a result of a recent experimental investigation. This theory leads in the above example to a working stress which would be between the extreme values, 14,000 lbs. per sq. in. and 20,000 lbs. per sq. in., as found by the preceding theories.

The question of the resistance to compound stress is of well recognized importance. Biaxial stresses occur in boilers, which must resist circumferential as well as longitudinal stresses; in plates which are supported all around the edge and are bent by a pressure from the side; in shafts which are bent and twisted at the same time. For that matter, any case of pure shear is an example of biaxial stress, because a shear is actually a tension combined with an equal compression in directions making 45° angles with the shearing stresses. Compressions in three direc-

[1] A. J. Becker: The Strength and Stiffness of Steel under Biaxial Loading, *Univ. of Illinois, Eng. Exp. Sta. Bull. 85*, 1916. This bulletin, besides reporting the author's tests, discusses the general problem of the resistance to combined stresses, and gives a bibliography. Among the preceding works should be mentioned: O. Mohr's discussion, "Welche Umstände bedingen die Elastizitätsgrenze und den Bruch eines Materials?" *Zeitschr. des Vereins Deutscher Ingenieure*, 1900, p. 1524, p. 1572 (also in his Abhandlungen auf dem Gebiete der technischen Mechanik, 2 ed., 1914, pp. 192–235); works by J. Guest (*Phil. Magazine*, July, 1900); W. Scoble (*Phil. Magazine*, 1906, p. 553); C. A. Smith (*Engineering*, July 10, 1908, March 5, August 20, December 24, 1909); L. B. Turner (*Engineering*, February 5, 12, 1909); W. Mason (*Engineering*, December 24, 1909); Cook and Robertson (*Engineering*, December 15, 1911); and P. W. Bridgman, (*Phil. Magazine*, July, 1912); also works by Föppl, Voight, and Kármán. A general discussion of the causes of failure is found, for example, in J. E. Boyd, Strength of Materials, 2 ed., 1917, Chapter 17.

tions occur in hooped guns and in other thick cylinders, and in spiral reinforced concrete columns; in these cases the increase of strength, when compressions act in three directions, is utilized.

The test data now at hand, although extensive, are limited when compared with the variety of stress combinations which would have to be tried in order to find the complete law of strength and failure even for one single material. Some of the combinations, for example, three equal tensions, are difficult to produce. The field best covered by experiment, as far as ductile materials are concerned, is that of biaxial stresses or plane stresses, such as occur in a plate resisting stresses in its own plane only (see the works quoted in the previous footnote). The result of the incompleteness of test data is that we are, as yet, in the stage of partially or approximately verified hypotheses. Further data are needed to verify or overthrow the working hypothesis which agrees best at present with experimental results, and which may have been selected, in view of the fact that designs must be made, as the best present choice; such a hypothesis may be satisfactory as an approximation and as the best choice that can be made until further information is available.

It is natural to select the simplest hypothesis which can be made to agree approximately with available data. Thus, when only few data were known *Rankine's maximum stress theory* was acceptable as the preferred hypothesis. When the importance of the difference which exists between the deformations caused by simple stresses and those caused by compound stresses of the same intensity was realized, then *Saint-Venant's maximum strain theory* gained ground, and for quite a long time it was used extensively as a basis of design, particularly in Europe. But later the experiments made by Guest and others, from about 1900 on (see previous footnote), showed a better agreement with the *maximum shear theory* (*Coulomb's hypothesis,* 1773, *Guest's law*, 1900) than with either the maximum stress or the maximum strain theories, and thus it was finally experimentally established that if one of the three hypotheses mentioned is to be selected as applying to the biaxial (plane) state of stresses in ductile materials, then Guest's law is preferable. It appears, however, that at different combinations of the stresses different laws might apply. In fact, A. J. Becker found, as a result of his above-quoted

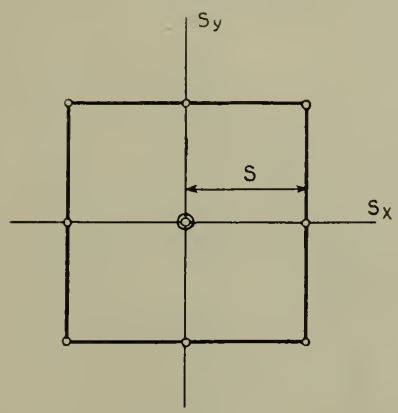
tests (1916), that with some combinations of biaxial stresses failure occurred at an almost constant maximum elongation, while with other combinations failure occurred at an almost constant maximum shear. This result led Becker to a *maximum shear and maximum strain theory,* according to which failure begins when either the shear or the strain reaches limiting values. He also found, upon a closer examination, that this conclusion was supported by the data from previous tests. Later experimental work (which will be mentioned presently) has pointed in the same direction.

If two different laws govern the failure, then it becomes important to know the field within which each law applies. A clear representation of the different laws is obtained most simply by adopting some *graphical representation of the state of stresses.* In the general case there are, at a given point, stresses in all directions; among these there are the three "*principal directions,*" perpendicular to one another, in which there are no shears. The normal stresses (tensions or compressions) in these directions are called the "*principal stresses.*" The principal stresses and their directions determine completely the state of stresses and of deformations at the point. One of the principal stresses is the greatest, another the smallest (largest negative) of all the stresses at the point. The maximum shear occurs in the two planes making 45° with the directions of the largest and of the smallest principal stress. The maximum shear is one-half the difference between the largest and the smallest principal stress. In the plane (biaxial) state of stresses the two principal directions are in the plane of the stresses, the third is perpendicular to the plane, and the principal stress in that direction is equal to zero.

If we assume that the material is isotropic at the point considered, that is, has the same qualities in all directions, thereby excluding such materials as wood, and to some extent wrought iron, then the directions of the principal stresses will not matter as far as the strength is concerned, and the important data will be the values of the three principal stresses, S_x, S_y, and S_z; they will, as stated before, determine the greatest shears and the strains. By laying off S_x, S_y, and S_z as rectangular coördinates a point (S_x, S_y, S_z) will be determined which represents the state of stresses. And each possible state of stresses defines such a point, which, for the sake of brevity, we shall call a stress point.

The condition of resistance to compound stress may then always be stated by requiring the stress point (S_x, S_y, S_z) *to be within or on the surface of a certain solid.* The surface of the solid determines the limiting stresses, and therefore the problem of resistance to combined stresses may be stated as the problem of determining this solid. If only plane states of stresses are considered, then the corresponding requirement is that the stress point (S_x, S_y), laid off in rectangular coördinates in the plane, must be within or on the boundary of a certain closed area; the boundary—a curve or a polygon—defines the stress limits. The experimental

FIG. 1.



Maximum stress.

proof that a certain boundary is the correct one is that the stress points, found by plotting the limiting stresses as determined from experiments, are on or near this boundary.

We shall begin by applying this graphical representation to the various hypotheses as referring to the plane state of stresses only. With limiting tensions and compressions $\pm S$ the stress field corresponding to *Rankine's maximum stress theory* is evidently a square (Fig. 1),[2] bounded by the lines $S_x = \pm S$, and $S_y = \pm S$. The corner ($+S$, $-S$) represents a pure shear in the directions of the diagonals; but tests show that the limiting shearing stress is in reality less than the limiting simple tension; or, the stress point ($+S_s$, $-S_s$) representing the actual limiting pure shear,

[2] The diagrams shown in Figs. 1 to 4 are given in Becker's previously quoted work.

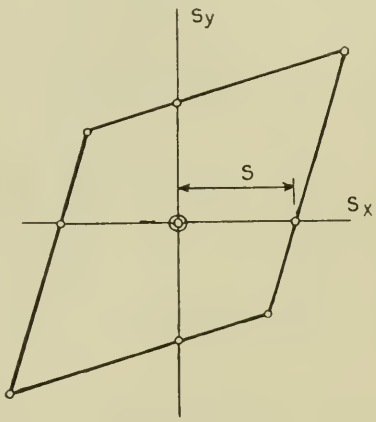
S_x, is at some distance inside the corner $(+S, -S)$. This proves that Rankine's theory can not be correct.

By *Saint-Venant's maximum strain theory* the tendency or the nearness to rupture is measured by the strain at stresses below the elastic limit. The unit elongation in the x-direction is given by the expression

$$\varepsilon_x = (1/E)\ (S_x - KS_y)$$

where E = modulus of elasticity, K = Poisson's ratio of lateral contraction (for steel about 0.3). If $S_x > S_y$, then ϵ_x is the largest elongation at the point. As E is a constant, it follows that also

FIG. 2.



Maximum strain.

the quantity $E\epsilon_x = S_x - KS_y$ will measure the tendency to rupture. Saint-Venant's hypothesis states that $S_x - KS_y$ measures the tendency to rupture even when the elastic limit has been exceeded. When $\pm S$ = limiting simple tension or compression, then the limiting biaxial stresses, S_x, S_y, are consequently defined by the equations

$$S_x - KS_y = \pm S \text{ and } S_y - KS_x = \pm S$$

defining four straight lines, enclosing a rhombus (Fig. 2). In the figure $K = 0.3$. Two of the vertices are $S_x = S_y = S/(1 - K) = 1.43\ S$, corresponding to equal tensions, and $S_x = -S_y = S/(1 + K) = 0.77$, corresponding to equal but opposite stresses, that is, pure shear in the 45°-directions. The stresses corresponding to both of these vertices are higher than the values found by

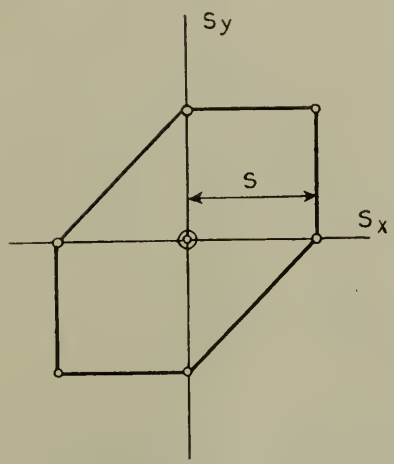
tests[3]; that is, the stress points representing the state of biaxial equal tensions and the state of pure shear are at some distance inside these vertices. Therefore, the working stresses derived from this hypothesis are not sufficiently safe.

The *maximum shear theory, Guest's law*, is represented in Fig. 3. In the plane state of stresses the principal stresses are S_x, S_y, and 0; that is, when $S_x > S_y > 0$, then the maximum shear is $\frac{1}{2}(S_x - 0) = S_x/2$, and when $S_x > 0 > S_y$ then the shear is $\frac{1}{2}(S_x - S_y)$. That is, the limiting stresses are defined by

$$S_x = \pm S,\ S_y = \pm S,\ S_x - S_y = \pm S$$

giving the hexagon shown.. The state of pure shear is repre-

FIG. 3.



Maximum shear.

sented by the point $(S/2, -S/2)$, the state of biaxial equal tensions by the point (S, S). However, experimental data indicate that the limiting values, $S/2$ for pure shear, and S for biaxial equal tensions, as defined by these points, are too small.

Becker's "maximum shear and maximum strain theory" is represented in Fig. 4. It is readily seen that this diagram represents a solution which lies between those indicated in Fig. 2 and Fig. 3. As Fig. 2 gave too large values and Fig. 3 too small

[3] See the previously quoted papers by Guest, Scoble, Smith, Turner, Mason, etc.

values in the cases of pure shear and of biaxial equal tensions, it might be expected that some such diagram as Fig. 4 would give a satisfactory agreement with experimental data. Becker indicates that the limiting shear is approximately $S_s = 0.6\,S$. If this value is correct, and if the limiting elongation is S/E (E = modulus of elasticity), then the limiting stresses will be determined by

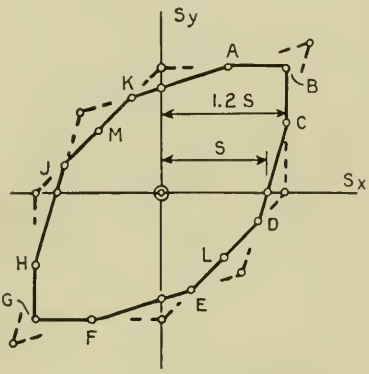
$$(1/2)S_x = \pm 0.6S, \quad (1/2)S_y = \pm 0.6S, \quad (1/2)(S_x - S_y) = \pm 0.6S,$$

and

$$S_x - KS_y = \pm S, \quad S_y - KS_x = \pm S.$$

These equations define the ten-sided polygon in Fig. 4, inside which the theory states that the stress point must remain. This

FIG. 4.

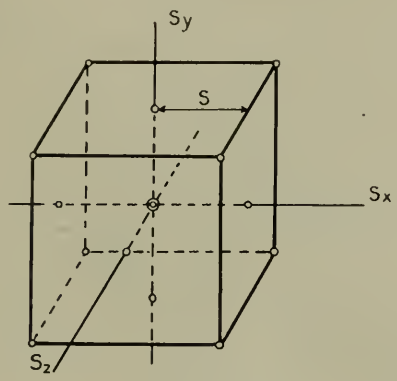


Maximum shear and maximum strain.

diagram may be found by starting from Fig. 2, cutting off the corners by superimposing a diagram which is similar to Fig. 2, but based on a limiting shear equal to 0.6 S instead of $S/2$. It is seen that the parts of the boundary ABC and FGH are governed by the shear in planes making 45°-angles with the xy-plane (compare Fig. 3), the parts DE and JK by shears in the two planes making 45° with the x-and y-axes, while the parts CD and KA are governed by the elongations (compare Fig. 2), EF and HJ by the shortenings. B represents the equal tensions $S_x = S_y = 1.2S$, while the points L and M define the limiting value of pure shear, $\pm S_x = \mp S_y = S_s = 0.6S$. While some individual tests have given lower values the ratio $S_s/S = 0.6$ was found to be justified by a rather large number of data taken from measurements of the

elastic limit and of the yield point; or, the stress points found by plotting the limiting stresses as determined by experiments, are on or near the boundary of the diagram in Fig. 4. A recent study by F. B. Seely and W. J. Putnam [4] of the relative values of elastic limits and yield points in shear and in simple tension for several grades of steel, led again to this same ratio, 0.6. That certain individual cases give slightly lower values is—as far as safety is concerned—counterbalanced by the fact that the ratio of ultimate shear to ultimate simple tension is rather larger than 0.6; it must be remembered that the "safety" is measured both relative to the ultimate stress and relative to the elastic limit. The value 0.6 and

FIG. 5.



Maximum stress.

the subsequent dimensions of Becker's diagram are, therefore, on the whole rather well justified by experimental data known at present.

At this place attention might be called to a method often used in Europe of indicating an "*equivalent stress*," sometimes called "ideal stress" [5] or "reduced stress" [6]; namely, a simple tension which is as "dangerous" or as "near failure" as the particular compound stress which is investigated. When, for example, S_x is positive and numerically greater than S_y, then

[4] F. B. Seely and W. J. Putnam: Relation between Elastic Strength of Steel in Tension, Compression, and Shear, *University of Illinois, Engineering Experiment Station Bull. 115*, 1919.

[5] A. Ostenfeld: Teknisk Elasticitetslære, 3 ed., 1916, p. 89.

[6] A. Föppl: Technische Mechanik, Vol. 3, ed. 1905, p. 63.

the equivalent stress, based on the diagram in Fig. 4, is seen to be the largest of the three values

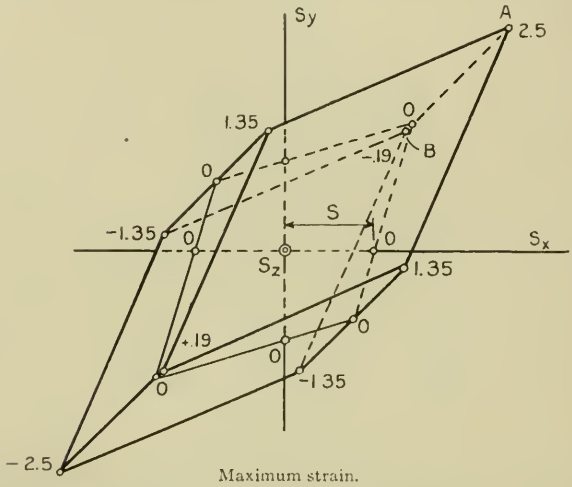
$$\frac{S_x}{1.2} \text{ corresponding to the side } BC \text{ (shear)}$$

$$S_x - KS_y, \text{ corresponding to the side } CD \text{ (elongation)}$$

$$\frac{S_x - S_y}{1.2} \text{ corresponding to the side } DE \text{ (shear)}$$

This "equivalent," "ideal," or "reduced" stress can be used as the measure of the tendency to failure. Similar expressions may be derived corresponding to the other sides of the polygon.

FIG. 6.



Maximum strain.

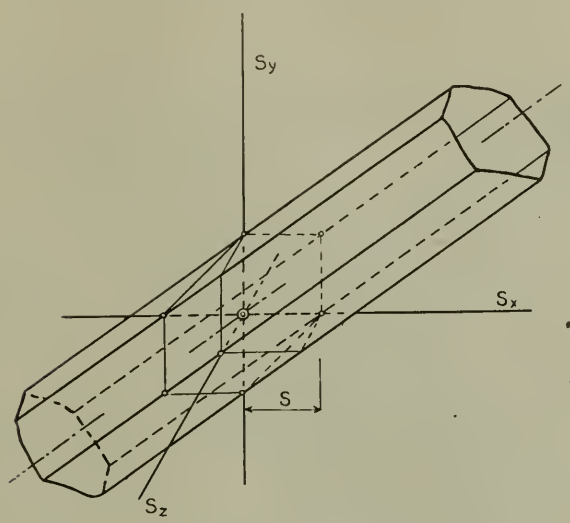
We shall now consider the *three-dimensional states of stresses.* That the solid representing the *maximum stress theory* is the cube shown in Fig. 5 is seen very readily. By the *maximum strain theory* the tendency to rupture is measured by such expressions as $E\epsilon_x = S_x - K(S_y + S_z)$, where ϵ_x is the elastic elongation in the x-direction. The limiting stresses are then defined by the relations

$$S_x - K\,(S_y + S_z) = \pm S,\ S_y - K\,(S_x + S_z) = \pm S,\ S_z - K\,(S_y + S_z) = \pm S$$

These six equations determine six planes, parallel in pairs, which enclose a skew parallelopiped, having its largest diagonal in the direction making equal angles with the x-, y-, and z-axes (the solid is shown in projection on the xy-plane in Fig. 6; the numbers indicate the values of S_z/S). This parallelopiped is then the

stress solid which represents Saint-Venant's maximum strain theory when applied to the general state of stresses in space. Its intersection with the xy-plane is the same as the diagram in Fig. 2. With $K = 0.3$, the vertex A representing three equal tensions has the coördinates $S_x = S_y = S_z = S/(1 - 2K) = 2.5S$; that is, $S = 16{,}000$ lbs. per sq. in. allowed in simple tension would correspond to 40,000 lbs. per sq. in. with three equal tensions (or

FIG. 7.



Maximum shear.

compressions). By solving three of the above equations the vertex B is found to have the coördinates:

$$S_x = S_y = \frac{1 - K}{1 - K - 2K^2}\, S, \quad S_z = \frac{-1 + 3K}{1 - K - 2K^2}\, S$$

or, with $K = 0.3$,

$$S_x = S_y = 1.35\, S, \quad S_z = -.19\, S$$

When $S_x > S_y > S_z$ then the maximum shear, as stated before, is $S_s = \frac{1}{2}(S_x - S_z)$. A simple tension S gives a shear $\frac{1}{2}S$. Hence, the solid representing the *maximum shear theory* is bounded by the planes

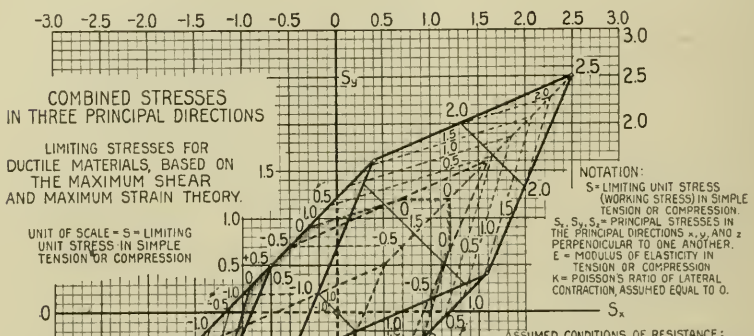
$$S_x - S_y = \pm S, \; S_y - S_z = \pm S, \; S_z - S_x = \pm S$$

Each of these six planes makes 45°-angles with two of the coördinate axes and is parallel to the third. The solid enclosed is a regular hexagonal prism (Fig. 7), the axis of which makes

equal angles with the three coördinate axes. The intersection with the xy-plane is the diagram in Fig. 3. That the prism is infinitely long is due to the fact that the shear remains small as long as the three principal stresses are almost equal; that is, the hypothesis allows unlimited almost equal stresses. That, for example, three exactly equal compressions (liquid pressure) would hardly break any material may be considered an established fact.

If the *maximum shear and maximum strain theory*, which was seen to be well-founded when applied to the plane state of

FIG. 8.



stresses, can be applied also to the case of three-dimensional stresses, then the corresponding stress solid will be of particular interest. In fact, the particular purpose of this paper was to indicate this stress-solid. In analogy with the preceding cases the limiting stresses are defined by the following relations:

Corresponding to the shear condition:

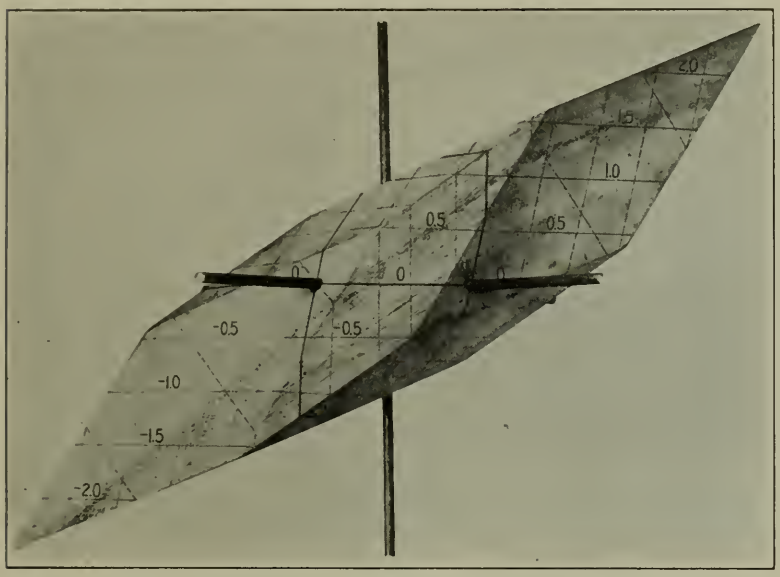
$$S_x - S_y = \pm 1.2\,S, \quad S_y - S_z = \pm 1.2\,S, \quad S_z - S_x = \pm 1.2\,S \ldots\ldots\ldots \quad (1)$$

and corresponding to the strain condition:

$$S_x - K\,(S_y + S_z) = \pm\,S, \quad S_y - K\,(S_x + S_z) = \pm\,S,$$
$$S_z - K\,(S_x + S_y) = \pm\,S \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

These twelve planes enclose a twelve-faced polyhedron, the projection of which on the xy-plane has been constructed in Fig. 8. It is determined by the intersection of a hexagonal prism similar to that in Fig. 7 (equations (1)) with the parallelopiped in Fig. 6 (equations (2)), and it is the solid remaining inside both of those solids. The stress solid is completely defined by the level curves shown, the numbers on which are the values of S_z/S. The level curves indicate the fields of the points (S_x, S_y)

FIG. 9.



for given values of S_z. The level curve $S_z = 0$ is the same as the diagram in Fig. 4. Poisson's ratio, K, was again assumed equal to 0.3. Fig. 9 shows a photograph of a model of this solid.

The equivalent simple tension (the "ideal" or "reduced" stress), corresponding to given values of S_x, S_y and S_z, is found as the highest value of S computed from the twelve expressions (1) and (2). Which one gives the highest value depends on the ratio (and signs) of the stresses. The stress solid can be used in answering this question. If the stress point (S_x, S_y, S_z) lies within a pyramid having its vertex at the origin and a certain one of the faces as its base, then the expression used as equation of that base gives the highest value of S. Thereby it is, for exam-

ple, possible to decide whether in a given case a shear failure or a strain failure would occur if the three stresses were increased in the same proportion.

After the above discussion had been written there appeared an article on the same subject by B. P. Haigh.[7] He proposes a new theory, namely, that the elastic limit is reached when the resilience or elastic energy per unit-volume has a certain definite value. He represents the laws following from this "*maximum resilience theory*" by the same graphical methods as those applied in the above discussion, and he finds thereby an ellipsoid instead of the stress solid in Figs. 8 and 9, and an ellipse instead of the diagram in Fig. 4. By comparing the proposed laws with results of previous tests (by Guest, Crawford, Batson, Mason, Turner, Sears, Scoble, and Cook and Robertson) he finds these results in better agreement with the maximum resilience theory than with either Guest's shear theory or St. Venant's strain theory. The agreement of the theory with the experimental results is least satisfactory in the case of equal biaxial tension, where the resilience theory, with Poisson's ratio $K = 0.3$, leads to the limiting stress $S_x = S_y = 0.845\ S$; that this value is too low is indicated both by the data quoted and, still more clearly, by Becker's results (to which no reference is made). With certain other combinations of stresses the agreement with the test data is very satisfactory, but in most of these cases the maximum shear and maximum strain theory gives very nearly the same results as the resilience theory. In fact, the diagram in Fig. 4 does not differ greatly from the ellipse, except at the two rectangular corners. Moreover, the limiting three-dimensional stresses found in the tests of thick cylinders by Cook and Robertson, and quoted by Haigh as supporting the resilience theory, agree very well with the maximum shear and maximum strain theory when the proposed shear limit $0.6S$ is used (instead of $0.5S$ with Guest's law). When all test data known at present are considered, then it seems that the experimental results support the maximum shear and maximum strain theory at least as well as or perhaps somewhat better than they do the maximum resilience theory. Further test data will be needed, however, before a final decision can be made.

[7] B. P. Haigh: The Strain-Energy Function and the Elastic Limit, *Engineering* (London), Jan. 30, 1920.

ELECTROLYTIC CONDUCTIVITY IN NON-AQUEOUS SOLUTIONS. IV. THE SOLVATION OF THE IONS OF TRIMETHYL-PARA-TOLYL-AMMONIUM IODIDE IN A NUMBER OF ORGANIC SOLVENTS.*

BY

HENRY JERMAIN MAUDE CREIGHTON,

Department of Chemistry, Swarthmore College, Member of the Institute.

THE question of a union between the solute and the solvent has been the subject of very systematic and extensive investigations by the late H. C. Jones and his co-workers, since the beginning of the century. The results of these researches led to the formulation of the *Solvate Theory of Solution,* which has been very useful in explaining certain apparent exceptions to the electrolytic dissociation theory of Arrhenius, presented by concentrated solutions. According to this theory, the ions and some of the molecules of the solute have the power to combine with more or less of the solvent.[1]

In a recent paper on the influence of the molecular magnitude of the solute on the conductance of its ions, Walden[2] has shown that the degree of solvation of the ions of the solute, *i.e.,* the number of moles of solvent combined with the ions, may be calculated from a knowledge of the limiting value of the conductivity, Λ_∞, of the solute, its molecular weight, M, the viscosity of the solvent, η_∞, and the molecular weight, M_0, of the latter. In this paper he has shown that the value of the constant in the expression:

$$\Lambda_\infty \cdot \eta_\infty = \text{const.}, \quad \ldots \ldots \ldots \quad (1)$$

depends upon the molecular weight of the solute; and that for solutions of a number of solutes in various solvents the product of the limiting value of the conductivity, the viscosity of the solvent, and the square root of the molecular weight of the solute has the same value, *i.e.,* at 25°,

$$\Lambda_\infty \cdot \eta_\infty \cdot M^{1/2} = 11.15. \quad \ldots \ldots \ldots \quad (2)$$

---

* Communicated by Professor Creighton.

[1] A resumé of the evidence bearing on the solvate theory of solution, and a detailed discussion of the significance of the theory will be found in this JOURNAL, **176**, pp. 479–564 and pp. 677–710 (1913).

[2] Walden, P.: Z. Elektrochem., **26**, 65 (1920).

When the ions of the solute are solvated, the molecular weight of the solute will have a greater value than that calculated from its chemical formula. In such cases, when the solute is not polymerized, the value of the constant in equation (2) will have a value smaller than 11.15, and the weight, Δ, of solvent combined with the ions is given by the expression:

$$\Delta = \left(\frac{11.15}{\Lambda_\infty \cdot \eta_\infty}\right)^2 - M. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

From this it follows that the number of moles of solvent combined with the ions, or the degree of solvation, is $\frac{\Delta}{M_0}$.

Recently the writer studied[3] the electrolytic conductivity of trimethyl-para-tolyl-ammonium iodide — $C_7H_7N(CH_3)_3I$ — in several organic solvents at 25°. The data obtained in this investigation have been used to calculate the extent to which solvation of the ions of trimethyl-para-tolyl-ammonium iodide occurs in a number of the solvents. The results of these calculations are given in Table I.

TABLE I.

Solvent	η_∞^{25}	Λ_∞^{25}	$\Lambda_\infty^{25} \cdot \eta_\infty^{25}$	$\Lambda_\infty^{25} \cdot \eta_\infty^{25} \cdot M^{1/2}$	$\Delta = \left(\frac{11.15}{\Lambda_\infty^{25} \cdot \eta_\infty^{25}}\right)^2 - M$	$\frac{\Delta}{M_0}$
Propylaldehyde	0.00435	120	0.414	6.89	448	7.73
Epichlorhydrin.	0.0103	44	0.453	7.54	328	3.44
Ethyl alcohol...	0.0112	48	0.538	8.96	152	3.30
Methyl alcohol.	0.00580	100	0.580	9.65	93	2.91
Benzaldehyde..	0.0140	33	0.462	7.69	305	2.88
Anisaldehyde...	0.0422	13	0.464	7.72	300	2.21
Propionitrile...	0.00413	143	0.591	9.84	448	1.44
Acetone.....	0.00316	188	0.594	9.89	75	1.29
Nitromethane..	0.00619	115	0.712	11.85	0	0
Nitrobenzene...	0.0182	38	0.692	11.52	0	0
Benzonitrile....	0.0125	54	0.675	11.22	0	0

Since it has been shown by Walden[4] that the iodine ion is not solvated in methyl alcohol, ethyl alcohol, acetone and nitrobenzene, it may be assumed that this ion has little or no tendency to combine with solvents. On this assumption, the degree of solvation of trimethyl-para-tolyl-ammonium iodide in the different solvents given in the last column of Table I probably represents the degree of solvation of the trimethyl-para-tolyl-ammonium

[3] Creighton, H. J. M., and Way, D. H.: This JOURNAL, 186, 675 (1918).
[4] Walden, P., *loc. cit.*, p. 69.

ion $[C_7H_7N(CH_3)_3]^+$. The results given in the table show that this ion does not combine with the solvent in solutions of either nitro-compound, or in solutions of benzonitrile; and that its greatest tendency to solvate is exhibited in solutions of aldehydes, the degree of solvation decreasing as the molecular weight of the aldehyde increases:

Solvent	M_o	$\frac{\Delta}{M_o}$
Propylaldehyde, C_2H_5CHO	58	7.73
Benzaldehyde, C_6H_5CHO	106	2.88
Anisaldehyde, $CH_3OC_6H_4CHO$	136	2.21

DEPARTMENT OF CHEMISTRY,
SWARTHMORE COLLEGE,
April 9, 1920.

On the Excitation of the Spectra of Carbon, Titanium, and Vanadium by Thermelectronic Currents. A. G. HEMSALECH. (*Philosophical Magazine*, March, 1920.)—Flawless plates of Acheson graphite, 37 mm. long, 10 mm. wide, and .95 mm. thick, covered on the upper side with a layer of powdered carborundum one-eighth of an inch thick to reduce the heat loss, were heated in air to temperatures ranging from 1700° to 3300° C. by electric currents of from 125 to 260 amperes. The maximum life of the plates at the higher temperatures was not more than 10 seconds.

As the temperature rises after the current begins to flow, yellowish vapors begin to form along the lower surface and a stream of such vapor rises from above the plate. At about 2400° C. the lower vapor turns bluish gray and assumes a sharply defined form, bulging downward. There is also a red-color region chiefly above the plate. The various colors are due to light emitted by vapors driven out from the carbon and the carborundum. When the plate is heated to about 3000° C. just below the lower surface there appears a sharply bounded band of pinkish hue one or two mm. deep, the "red fringe." "To investigate its origin, the plate was put in a horizontal magnetic field, so that the current and lines of force were at right angles. At 2700° the red fringe is usually invisible. When the force exerted on the current by the field was downward at this temperature, the fringe came to view. On reversing the field it disappeared. At 3000° C., at which temperature the fringe is normally developed, the application of the field in one direction makes the fringe appear above the plate and causes it to disappear from below it. The removal of the field is followed by the disappearance of the fringe above and by its reappearance below." Part of the heating current had passed out of the graphite plate into the space below and its path was revealed by the formation of the red fringe. Hemsalech distinguishes this current which he designates "thermelectronic" from

the thermionic currents of Richardson, holding that the former are due to the displacement of lighter particles than are the latter.

"Spectroscopic examination has revealed the existence of two entirely different and distinct emissions by the luminous vapors in the neighborhood of the heated plate. One of these emissions is controlled by the plate temperature and is due to thermo-chemical excitation. The lines and bands which compose its spectrum are observed to die out only gradually on passing away from the plate. The second emission is confined to the immediate vicinity of the plate, and in extent it coincides with the red fringe. It is further shown that this emission is controlled by the thermelectronic current and is therefore due to thermo-electric excitation. The characteristic feature of its spectrum is that its lines and bands, unlike those of the first emission, stop quite abruptly at the lower edge of the red fringe."

The red-fringe spectrum is made up of carbon bands, lines of titanium and of vanadium and of a group of hazy red bands attributed to the oxide and carbide of calcium.

G. F. S.

An Attempt to Determine if Common Lead Could be Separated Into Isotopes by Centrifuging in the Liquid State. J. JOLY and J. H. J. POOLE. (*Philosophical Magazine,* March, 1920.)—Among the descendants of both the thorium and the uranium radioactive family is an element which is isotopic with ordinary lead but differing from it a little in atomic weight and in density. Ordinary lead seems to be a mixture of these two isotopes. An attempt was made to separate the two constituents in a centrifuge as milk and cream are separated. The lead was maintained liquid by an electric current. After the centrifuge had been run for an hour at 9000 r.p.m. the lead was removed in six portions and the density of the top and bottom lots was measured. No evidence at all for any separation effect was obtained. After the initiation of the experiments a discussion of the possibilities of the method employed made clear that with the peripheral velocities of the centrifuge no separation should be detected, as the errors of observation would mask any difference of density. The Irish investigators are, however, confident that with a centrifuge running with higher peripheral velocity definite results should manifest themselves.

In a second paper in the same issue of the *Philosophical Magazine* the same authors report that they failed to separate the silver from the lead in alloys of these two metals, thus failing to find a substitute for cupellation. In the case of Pb-Sn and Pb-Sn-Bi alloys there was found a distinct difference between the upper and lower lots, amounting in one case to 1.8 per cent. "It is of interest that a definite alloy like tin-lead alloy, which is of the composition PbSn, should be capable apparently of being separated by the action of the centrifuge."

G. F. S.

PHENOMENA OF DRYING WOOD.*

(Second Article.)

An Analogistic Explanation of "Casehardening" or the Relations of "Set" and Stresses that Occur in Drying Wood.

BY

HARRY D. TIEMANN,

Physicist and Expert in Kiln-drying, United States Forest Service, Forest Products Laboratory, Madison, Wis.

INTRODUCTION.

In a previous article (July, 1919, pages 27–50) an explanation was given of the peculiar conditions of shrinkage, internal stresses and "sets." These conditions occur when a green piece of wood dries, and they give rise to the phenomenon of "casehardening," as it is called for lack of a more definite term. An analysis was also given of the stresses that occur progressively from the surface to the interior of the block. It is because of these phenomena, and particularly because of the "setting" of the molecular structure as a result of the process of drying, that wood may be bent in various ways and will remain so without restraint after it is dry. If the piece of bent wood is steamed, however, or even thoroughly soaked, it will return nearly to its original shape, provided it has not been stressed beyond the rupture point in bending. Furthermore, these same phenomena are what cause all the troubles encountered in drying wood, such as surface checking, "honeycombing" or internal checking, and warping.

To the uninitiated, or the person who has not made a thorough study of the subject, the behavior of wood in drying is frequently mystifying, and erroneous ideas and conclusions have resulted. There are three *partially independent* variables and one *dependent* variable that enter into the consideration. These are, first, the normal shrinkage of the wood with the removal of the hygroscopic moisture; second, the "set" or fixation of the molecular structure with a decrease in moisture; and third, the increase

* Communicated by the Director of the Forest Products Laboratory, Madison, Wisconsin.

in strength and hardness of the wood substance, each of these three being directly dependent upon the moisture condition, which is the fourth variable. All of these factors influence the internal stresses and the resulting form or dimensions of the block. It should be further noted that the shrinkage is a complex variable dependent also upon the direction of the grain and the density of the block. In general, normal shrinkage is twice as much circumferentially of the log, and about one-fiftieth as much longitudinally, as it is radially.

There is a mechanical analogy to the inter-relation of shrinkage, "set," strength, and moisture in which there is so close a correspondence to the actual physical phenomena that it may be used not only to clarify the conception, but even to predict what will take place under a given set of new conditions. It is the purpose of this paper by means of this simple mechanical analogy to make these somewhat vague ideas more clear.

A CLARIFYING ANALOGY.

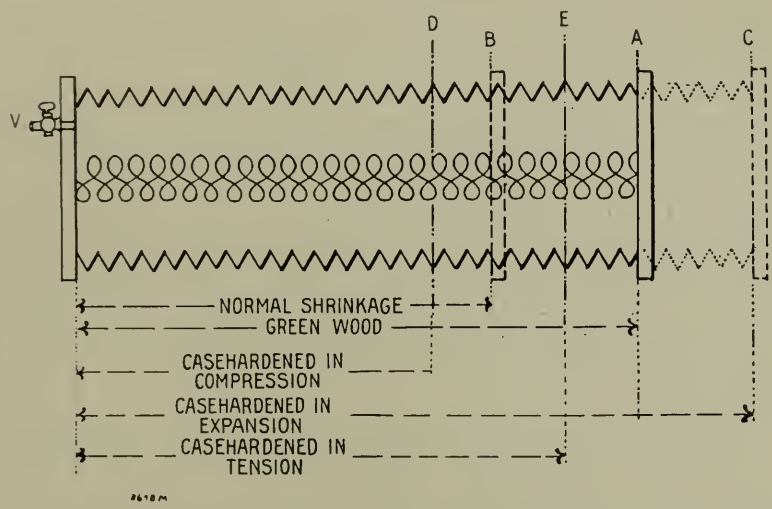
Imagine an "accordion-plaited" bellows (Fig. 1)[1] about a foot long and, say, three inches square, hermetically tight, but with a small air valve, *V*, in one end, which may be opened or closed to permit the outflow or inflow of air. Also imagine inside the bellows a coiled-wire spring of medium strength but sufficiently strong to hold the bellows open in a neutral position, so that, after being stretched or compressed, the accordion will return to this neutral position. This may be called position *A*.

Now, when the valve is open, we have very nicely represented a piece of green or steamed wood. The bellows may easily be stretched or compressed and will return to its initial position *A*, the spring alone offering resistance to deformation. Now draw a partial vacuum and close the valve; the neutral position becomes less than *A*, say *B*, and a piece of dry wood is represented. The apparatus may now be extended or compressed with much more difficulty, as not only the spring but the air also offers resistance to deformation; however, it will always return to the position *B*. This represents the increase of strength that occurs in dry as compared with green wood, as well as the "set" that takes place

[1] The illustration is presented with the caution that the air, spring, and other figures used are wholly analogical in significance, and that it is the relations and effects that are to be compared.

under normal shrinkage. On the other hand, suppose that through the open valve air is forced into the bellows, and the valve is then closed. The neutral position will now be greater than *A*, as *C*, representing a "set" in an expanded condition of the wood. Or, suppose that a greater vacuum than before is created within the bellows, so that the neutral position becomes less than *B*, say *D*, with the valve closed. This represents a "set" condition in which the wood is compressed beyond its normal shrinkage. Both *C* and *D* represent a "set" condition of the wood, which is the primary factor in causing casehardening and

FIG. 1



also in fixing the shape of bent wood as a result of the process of steaming, bending and subsequent drying in the bent condition.

This analogy is particularly illuminating, since it may be used to interpret and predict actual phenomena that take place in wood, although the causes are, of course, not identical in the two instances. The apparatus with the open valve represents green or steamed wood when it is in a plastic condition and may easily be stretched or compressed. Closing the valve is equivalent to "setting" the wood, and the matters of shrinkage or dimensions are dependent upon the air pressure in the bellows at the time the valve is closed. Shrinkage is represented by drawing a vacuum with the valve open, and the "setting" takes place at any

degree of vacuum or air pressure when the valve is closed. It will be seen that there is always a tendency for the wood to return to its initial green condition whenever it is soaked or steamed, just as the accordion will return to its position *A* as soon as the valve is opened. Shrinkage to *B* is "normal shrinkage," but to *D* it is "set," under compression stress, and to *E* or *C* under tensile stress.

It seems probable that there is a very similar occurrence with respect to the molecules of the wood itself. Although the molecules have a normal position relative to one another, to which they tend to return when they become wet after being stressed, they may be displaced from this position by means of force, and when dried in the displaced position they become "set" temporarily, that is, they become fixed in this new situation. When sufficient moisture is added to render them flexible again (equivalent to opening the air valve) they return to the original condition. In drying normally (not under any stress), the removal of the water draws the particles together to a certain degree, and they also become "set" normally, as in position *B* of the illustration; but, while wet (valve open), if they are compressed to a greater extent than this, they will become "set" in a still closer position, as at *D* in the accordion. If normal shrinkage is prevented by tensile stress (with valve open) during shrinkage, the wood will become "set" (when valve is closed) in an intermediate position, as at *E*.

There are two kinds of internal stress resisting applied forces—one a fixed quantity, like the force of the spring within the accordion; and another, which appears to be variable and is dependent upon the distortion of the wood during its process of drying from the green or wet condition. This second stress corresponds to that offered by the air pressure within the bellows when the air valve is closed, and is of a temporary nature.

THE SELECTION OF GLASS FOR THE MANUFACTURE OF AMPULS.*

BY

GEORGE E. EWE,

Chief Chemist, H. K. Mulford Company, Philadelphia.

THE selection of and requirements for glass bottles for storing the ordinary elixirs, fluidextracts, powders, tablets, etc., employed in pharmacy is a crude process, indeed, in comparison with the careful tests required for the selection of a proper glass for the manufacture of ampuls. This care is necessitated by reason of the fact that unselected glass may possess sufficient free alkali, or may be capable of yielding sufficient free alkali under the stress of the sterilization process which ampul solutions are required to undergo, or may yield sufficient alkali in the period during which they are necessarily kept in stock before being sold, to cause the precipitation of a portion of the alkaloidal base of a solution of alkaloidal salt when placed in the ampuls, and because unselected glass may throw off spicules or splinters of glass under the stress of the sterilization process or during storage. It is sufficient merely to point out, in order to show the unsuitability and even danger in the use of improperly selected glass, that precipitation of alkaloidal base will result in the lowering of the efficacy of an ampul solution upon which a physician may be relying in a serious case of illness and the production of spicules or splinters of glass in the ampul solution may result in discomfort, local irritation, or possibly more remote and more dangerous consequences. The use of a slight addition of acid to ampul solutions in an effort to correct for the alkalinity of unselected or improperly selected glass is contra-indicated in view of the fact that glass can be made or selected which requires no use of acid. The use of acid is also contra-indicated because acidity is usually productive of irritation at the site of injection.

In outlining tests for the selection of glass for the manufacture of ampuls the working of the glass under the flame must also be considered. In addition, other tests which may act as checks on the "alkalinity," "spicule" and "flame" tests are

* Communicated by the Author.

frequently resorted to. The series of tests mentioned below will, as a rule, be sufficient for proper selection of glass, if applied "secundum artæ." However, the "art," particularly the "flame" testing can be attained only by practical experience.

TESTS FOR THE SELECTION OF GLASS FOR THE MANUFACTURE OF AMPULS.

Size of tubing, thickness of wall, freedom from certain proscribed ingredients, color: in accordance with specifications.

"Working under the flame": can be judged only by practical experience obtained by comparison of many varieties of glass.

Standard: greatest ease in working consistent with the other requirements.

"Alkaloidal Alkalinity Test"—"General."—A 1 per cent. solution of U. S. P. morphine sulphate or a 0.2 per cent. solution of U. S. P. strychnine sulphate in normal saline solution must not develop crystals or become turbid or opalescent when sterilized under practical conditions in ampuls made from the glass undergoing test; the ampuls having been treated with dilute hydrochloric acid and finally thoroughly washed free from acid and dried before the alkaloidal solution is placed in them. The preferred test is the "particular" one which is in all respects similar to the "general" test except that the particular solution which is intended to be marketed in the ampuls is used in place of the morphine sulphate or strychnine sulphate solutions.

"Spicule Test."—Work the glass into ampuls. Place a 0.6 per cent. NaCl solution (or any particular solution) in the ampuls; seal and sterilize under practical conditions. The solution is then carefully examined under a magnifying glass for spicules or splinters of glass.

Exact conformity with the above tests is absolutely necessary in order to permit the use of any particular glass for the manufacture of ampuls.

The following tests are applicable for comparative purposes only, and are occasionally employed as confirmatory checks:

"Phenolphthalein Alkalinity Test."—Treat the glass with dilute HCl followed by very thorough washing. Boil a sample corresponding to 500 sq. centimetres of surface for 16 hours with distilled water, keeping the sample covered with fresh additions of water as required. Remove the glass, add 1 c.c. phenolphthalein test solution to the water in which the glass was boiled

and titrate to neutrality. Make a correction on the water, vessel in which the boiling was conducted, locality in which the test was carried out, etc., by running a blank under precisely the same conditions employed in making the test, and at the same time. Report alkalinity as milligrams of NaOH per 100 sq. cm.

"*Loss to Water Test.*"—The sample used in the "phenolphthalein alkalinity test" is weighed before and after boiling. Report loss as milligrams per 100 sq. cm.

"*Vulnerability to Alkaline Fluids Test.*"—Repeat the "loss to water test," using a new sample and using 2 per cent. sodium carbonate solution in place of water, keeping up the volume by fresh additions of water only. Report loss as milligrams per 100 sq. cm.

"*Phenolphthalein Alkalinity Autoclave Test.*"—Water containing a few drops of phenolphthalein test solution is placed in the ampul (which has previously been acid-washed and thoroughly rinsed with distilled water); the ampul is sealed and autoclaved at 12 lbs. steam pressure for 45 minutes. At the end of this time the tube is carefully examined for color and spicules. A pink color indicates alkalinity.

"*Phenolsulphonephthalein Alkalinity Autoclave Test.*"—In all respects this is similar to the preceding test with the exception that a yellowish solution of phenolsulphonephthalein is used instead of phenolphthalein and the autoclaved liquid is examined for any reddish tint which may develop.

The following table shows some typical results obtained by the use of the several tests mentioned above in glass tubing offered for the manufacture of ampuls:

Sample No.	Color.	"Flame" test.	"Spicule" test.	"Phenolphthalein Alkalinity" test.	"Loss to Water" test.	Suitability.
1	Flint	O. K.	None	0.098 mgm.	0.7 mgm.	O. K.
2	Flint	Works hard	Spicules	.....	4.2 mgm.	Not O. K.
3	Flint	Works easily	Spicules	.....	1.9 mgm.	Not O. K.
4	Flint	Works easily	None	Undeter. trace	0.61 mgm.	O. K.
5	Flint	Works easily	None	0.102 mgm.	1.1 mgm.	O. K.
6	Flint	Works hard	Spicules	.....	Unweighable	Not O. K.
7	Flint	Works easily	None	.....	0.62 mgm.	O. K.
8	Flint	Works easily	None	.....	0.49 mgm.	O. K.
9	Flint	Works easily	None	.....	3.2 mgm.	O. K.
10	Flint	Works easily	A few spicules	.....	4.4 mgm.	Not O. K.

All of these samples yielded perfect results in the "alkaloidal alkalinity" test. As a matter of fact, after a satisfactory source has been established, it is only occasionally that a sample fails to answer this requirement, but this occasional exception illustrates the necessity for the application of this test.

The relation between the alkalinity yielded in the "phenolphthalein alkalinity" test and the result of the "alkaloidal alkalinity" test was not determined, the "phenolphthalein alkalinity" test being rejected in favor of the shorter and more practical "alkaloidal alkalinity" test.

The phenolphthalein and phenolsulphonephthalein alkalinity autoclave tests are used by some workers, but they are open to the criticism that they bear no practical direct relation to the possible use of the glass for ampul purposes, whereas in the same time and with no more labor a direct result can be obtained by the use of the "alkaloidal alkalinity test."

No definite information can be obtained regarding the possible formation of spicules by a glass, from its working qualities under the flame. In the experience of some workers, the hard glasses appear to suffer surface scaling under the influence of the moisture and heat used in autoclaving, whereas in the experience of others, the more easily worked and more soluble glasses yield spicules by surface erosion due to solution of the alkaline radicle of the glass.

The results yielded by the application of the "phenolphthalein alkalinity," "loss to water" and "vulnerability to alkaline fluids" tests to some samples of glass tubing, bottles, Erlenmayer flasks, test tubes and beakers are herewith appended as a matter of comparison and of interest:

Sample.	Color.	"Phenolphthalein Alkalinity" test.	"Loss to Water" test.	"Vulnerability to Alkaline Fluids" test.
Tubing.....	Flint	Undeterminable trace	Unweighable	21.0 mgm.
Tubing.....	Flint	.....	1.5 mgm.	.....
Tubing.....	Flint	Undeterminable trace	Unweighable	30.0 mgm.
Tubing.....	Flint	.....	1.17 mgm.	.....
Tubing.....	Flint	Undeterminable trace	Unweighable	24 mgm.
Tubing.....	Flint	Undeterminable trace	Unweighable	8.25 mgm.
Tubing.....	Flint	.....	1.2 mgm.	.....
Tubing.....	Flint	.....	4.0 mgm.	22.5 mgm.
Tubing.....	Flint	.....	2.5 mgm.	43.5 mgm.
Tubing.....	Flint	.....	0.62 mgm.	.....
Tubing.....	Flint	.....	2.5 mgm.	31.5 mgm.
Tubing.....	Flint	.....	3.0 mgm.	27.5 mgm.
Tubing.....	Flint	.....	3.1 mgm.	.....
Tubing.....	Flint	.....	3.5 mgm.	24.0 mgm.
Tubing.....	Flint	.....	Unweighable	9.25 mgm.
Tubing.....	Flint	Undeterminable trace	Unweighable	6.5 mgm.
Tubing.....	Flint	.....	Unweighable	20.0 mgm.
Tubing.....	Flint	.....	Unweighable	17.5 mgm.
Tubing.....	Amber	.....	Unweighable	2.65 mgm.
Tubing.....	Amber	.....	Unweighable	2.0 mgm.
Tubing.....	Amber	.....	8.0 mgm.	56.5 mgm.
Tubing.....	Amber	.....	1.5 mgm.	22.5 mgm.
Tubing.....	Amber	.....	3.0 mgm.	27.5 mgm.
Tubing.....	Amber	.....	4.0 mgm.	19.0 mgm.
Tubing.....	Amber	.....	5.0 mgm.	12.5 mgm.
Tubing.....	Amber	.....	8.0 mgm.	25.0 mgm.
Tubing.....	Amber	.....	10.0 mgm.	57.5 mgm.
Tubing.....	Amber	.....	Unweighable	7.5 mgm.
Tubing.....	Amber	.....	Unweighable	7.8 mgm.
Tubing.....	Blue....	.....	0.15 mgm.	1.8 mgm.
Bottle.....	Flint	.....	0.45 mgm.	.....
Bottle.....	Flint	.....	0.59 mgm.	.....
Bottle.....	Flint	.....	0.39 mgm.	.....
Erlenmayer flask.....	Flint	.....	0.0107 mgm.	.....
Test tubes..	Flint	Undeterminable trace	0.28 mgm.	.....
Beaker.....	Flint	Undeterminable trace	3.0 mgm.	.....
Beaker.....	Flint	.....	Unweighable	3.3 mgm.
Beaker.....	Flint	Undeterminable trace	Unweighable	18.5 mgm.
Beaker.....	Flint	Undeterminable trace	Unweighable	13.0 mgm

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The Measurement of Projectile Velocities. PAUL E. KLOPSTEG and MAJOR A. L. LOOMIS. (*Jour. Am. Inst. Elec. Eng.*, Feb., 1920.) —During the war the Aberdeen Chronograph was developed. By reason of the use of standard parts one complete instrument could be delivered in one working day. Under actual working conditions one round could be fired and all the readings taken in forty-five seconds.

Instead of breaking electrical circuit by rupturing a wire, as was done in the Boulengé chronograph, the projectile closed the circuit by making contact between two pieces of lead foil. When contact is thus established, current flows through the primary of a transformer. The current developed in the secondary flows through the registering device. A constant speed motor carries on its vertical shaft an aluminium drum within which fits a strip of specially prepared paper. The current from the secondary passes as a spark from a point to the metal of the drum, making a mark on the paper. After the projectile has travelled 50 feet further, it closes a second circuit and a second mark is registered on the paper. With a fixed distance between targets and with constant speed of rotation of the drum the velocity sought was proportional to the distance between the two marks on the strip of paper. A scale was accordingly made on which the velocity was read off directly merely by applying the paper to it.

G. F. S.

Caramel.—G. P. PLAISANCE and HELEN MONSCH, of the Iowa State College and Agricultural Experiment Station, have studied the occurrence of furfural in caramel (*Journal of Home Economics*, 1917, ix, 167–171). Caramel is used as a coloring, *e.g.*, in artificial vanilla extract, and is formed from sugar in cooking. Furfural, furfurole, or furfuraldehyde is an heterocyclic aldehyde which is volatile in steam. It is somewhat toxic, thus 0.1 gram causes headache in man and 0.5 gram kills a cat or a rabbit. Some furfural is formed when sugars, especially cane sugar, are caramelized at a temperature ranging from 180° to 200° C.; the greatest production of furfural noted was 0.944 gram from 1 kilogram of cane sugar on caramelization for four minutes at 200° C. However, the furfural is completely expelled if the caramel be boiled with an equal amount of water for ten minutes in an open pan. No precautions to prevent the injurious action of furfural are necessary when the food is cooked in the presence of water after caramelization, as in the preparation of cakes, frostings, and rice pudding. In candy-making the cooking should be conducted at as low a temperature as possible, since the yield of furfural increases with the temperature. Care should be taken to prevent caramelization in the baking of fruits; it is desirable to boil caramelized fruit syrups with an equal volume of water for ten or fifteen minutes before serving them.

J. S. H.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

AN INTEGRATION METHOD OF DERIVING THE ALTERNATING CURRENT RESISTANCE AND INDUCTANCE OF CONDUCTORS.[1]

By Harvey L. Curtis.

[ABSTRACT.]

In connection with some work on alternating current resistance and inductance, the Bureau of Standards recognized the need of formulas taking into consideration the so-called "Skin Effect" due to the proximity of the conductors.

The solution of the problem was met by a process of integration. The conductor is divided into infinitesimal filaments by surfaces which coincide with the lines of flow. The magnetic field at any point is the sum of the magnetic fields of all these filaments. The counter-electromotive force in a filament is determined by the rate at which the magnetic fields of all the others cut this filament.

Formulas for the alternating current resistance and inductance of a straight cylindrical conductor were derived by both the use of real and imaginary power series. These formulas correspond exactly with the asympotic formulas of Russell (*Phil. Mag.*, 17 p. 524, 1909).

The same method is applied to a return circuit making use of imaginary series, and formulas for the alternating current resistance and inductance are derived. Values computed by these formulas are compared with experimental results.

THE CHARACTERISTICS OF STRIÆ IN OPTICAL GLASS.[2]

By T. T. Smith, G. E. Merritt, and A. H. Bennett.

[ABSTRACT.]

Striæ are imperfections in optical glass which are revealed by, and cause consequent damage because of, their refractive index being slightly different from the surrounding glass. Various methods for detecting their presence are described and photographic illustrations by a highly sensitive method given.

* Communicated by the Director.

[1] Scientific Paper No. 374.

[2] Scientific Paper No. 373.

The comparative effects of striæ on the definition given by binocular prisms, in which striæ are present in different degrees, are exhibited by photographs of an artificial star taken through these prisms. Prisms which had been discarded because of the presence of striæ in them, except where these show up in dense nests, were found to give as good definition as those having no appreciable striæ.

The refractive indices of the striæ were measured for a number of samples by a total reflection refractometer and found to be above or below that of the surrounding glass by about 2 in the fourth decimal place.

From the investigation, it is concluded that in most visual work a few striæ do real damage only when in focus or nearly in focus in the field of view. The scattering effect of a few striæ is probably detrimental only in astronomical and certain kinds of microscopic work.

A NEW CADMIUM VAPOR ARC LAMP.[3]

By Frederick Bates.

[ABSTRACT.]

FOR some years numerous experiments have been carried out by a number of investigators with the object of obtaining a cadmium vapor lamp similar to the mercury vapor lamp. This has been done owing to the necessity for securing a stable monochromatic red-light source of high intensity. When pure cadmium is distilled into the quartz lamp and freezes, the metal adheres to the silica with such tenacity as to either crack the lamp or peel strips of the silica from the walls. If such a lamp be filled with a cadmium-mercury alloy, the cadmium spectrum appears but faintly, and the position of its principal lines in the spectrum with respect to the mercury lines is such that spectrum filtration with a wide slit is impracticable. The lack of intensity in the cadmium is due to the fact that its vapor pressure is relatively low compared with that of mercury.

In the present investigation it was discovered that the metal gallium would readily alloy with cadmium, and that a very small quantity, less than one per cent., was sufficient to radically change the character of the cadmium and greatly reduce its tensile

[3] Scientific Paper No. 371.

strength. All breakage of the lamp was eliminated. In using this alloy in a quartz vapor lamp, the cadmium spectrum is obtained with great brilliancy and purity. Although gallium melts at approximately 30° C., its boiling point is above 1600° C., and its vapor pressure is so low that the spectrum of gallium is practically absent, the cadmium vapor acting as the carrier of the electric energy. The utilization of the cadmium spectrum is greatly facilitated by the fact that the gallium lines appear but faintly and that the spectrum of gallium has no lines between 4200A and 6400A. A lamp of this type, using lead seals to render the electrodes proof against leakage can be operated continuously with no variation in the high intensity of the cadmium lines and appears to have an indefinite life.

WAVE LENGTHS LONGER THAN 5500Å IN THE ARC SPECTRA OF SEVEN ELEMENTS.[4]

By C. C. Kiess and W. F. Meggers.

[ABSTRACT.]

THE concave grating spectograph of the Bureau of Standards was used to photograph the yellow, red and infra-red arc spectra of titanium, chromium, manganese, molybdenum, tungsten and uranium. This work is a continuation of a program of standard wave-length determination and spectroscopic analysis which has as one of its objects the mapping of the spectra of chemical elements as far out into the region of long wave lengths as modern photographic methods will permit.

The spectrograms were made on photographic plates sensitized to the long waves by bathing in solutions of dyes. Recently "made-in-America" dyes were used for many of the plates and were as effective in their photosensitizing action as the imported ones.

The wave lengths of more than 2500 spectral lines were derived from the measurement of the plates. These wave lengths extend from the green at 5500 Å into the infra-red beyond 9700 Å. So far as known, impurity lines and spurious lines have been eliminated from the wave-length tables. Frequency differences which are suspected of being constant have been found in each of the spectra here presented.

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[4] Scientific Paper No. 372.

RECOMMENDED SPECIFICATIONS FOR WHITE PAINT AND TINTED PAINTS MADE ON A WHITE BASIS, SEMI-PASTE AND READY MIXED.[5]

[ABSTRACT.]

PREPARED and recommended by the U. S. Interdepartmental Committee on Paint Specification Standardization January 26, 1920. This committee was appointed at the suggestion of the Secretary of Commerce, and consisted of representatives of the War, Navy, Agriculture, Interior, Post Office, Treasury, and Commerce Departments, the Railroad Administration, the Panama Canal, and the Educational Bureau of the Paint Manufacturers' Association of the United States. The committee submitted a preliminary draft of the specifications to a large number of representatives of the paint and varnish manufacturers, and gave careful consideration to the replies received.

RECOMMENDED SPECIFICATIONS FOR RED LEAD, DRY AND PASTE.[6]

[ABSTRACT.]

PREPARED and recommended by the U. S. Interdepartmental Committee on Paint Specification Standardization January 26, 1920. This committee was appointed at the suggestion of the Secretary of Commerce, and consisted of representatives of the War, Navy, Agriculture, Interior, Post Office, Treasury, and Commerce Departments, the Railroad Administration, the Panama Canal, and the Educational Bureau of the Paint Manufacturers' Association of the United States. The committee submitted a preliminary draft of the specification to a large number of representatives of the paint manufacturers, including the manufacturers of red lead, and gave careful consideration to the replies received.

AN INVESTIGATION OF THE PHYSICAL PROPERTIES OF DENTAL MATERIALS.[7]

By Wilmer H. Souder and Chauncey G. Peters.

[ABSTRACT.]

PROPERTIES, such as crushing strength, flow, thermal and chemical expansion, chemical composition, electrode-potentials

[5] Circular No. 89.
[6] Circular No. 90.
[7] Technologic Paper No. 157.

and thermal reactions have been investigated. Additional phases, such as method of manipulation, time, temperature, etc., were found to exert definite influences upon the materials.

A number of commercial alloys, together with some special alloys, were tested. The thermal expansion of amalgams was found to be considerably greater than the expansions of normal teeth.

The apparatus generally used in testing these materials was found to be unsuited for accurate observations. More suitable instruments were selected and it is thought that the data supplied in this paper are of the highest accuracy and may be safely used as the basis for clinical interpretations.

The paper includes 25 photographs or drawings and three tables setting forth details of the investigation.

TWELFTH ANNUAL CONFERENCE ON WEIGHTS AND MEASURES, 1919.[8]

[ABSTRACT.]

THE Annual Conference on Weights and Measures is a national organization composed of State and local weights and measures officials throughout the United States. This body meets annually at the Bureau of Standards, Washington, D. C., for the purpose of discussing and solving problems relating to weights and measures, such as uniform legislation, rules and regulations and methods of enforcement of weights and measures laws, specifications and tolerances for all commercial apparatus, and the proper inspection and test of apparatus, etc. The present meeting was the twelfth one held, and the first since 1916, the sessions having been discontinued during the war. This report, which is a stenographic record of the proceedings, includes all papers read and resolutions adopted. Perhaps the most important single accomplishment of this Conference was the discussion upon and the tentative adoption of a set of specifications and tolerances for liquid-measuring pumps, especially those used in the sale of gasoline, kerosene, etc. It was agreed by the members that these should be thoroughly studied and tried out in the field and that final action upon them should be taken at the next meeting. The unsatisfactory condition of liquid-measuring pumps in all

[8] Miscellaneous Publication No. 41.

parts of the country rendered action on this important subject imperative if the purchaser was to receive the correct amounts.

Consideration was also given to a number of other subjects of importance, including the progress made in the various States and cities; the necessity of the Federal regulation of type of apparatus; the proper method of sale of ice and wood; the testing of railroad track and mine scales; the marking of wrapped hams and bacon with the net weight; the standardization of shipping containers; and the adoption of the metric system of weights and measures.

THE EXTRACTION OF RUBBER GOODS.[9]

By S. W. Epstein and B. L. Gonyo.

[ABSTRACT.]

THIS paper makes a complete study of the various extracts as determined in the analysis of rubber goods. The advantage of the use of mixed solvents, namely acetone-carbon bisulphide and acetone-chloroform, over the methods previously employed is described with considerable detail.

A mixture of 55 per cent. carbon bisulphide and 45 per cent. acetone by volume, boiling constantly at 34.25° C., is adopted rather than the acetone-chloroform mixture because of the less solvent effect of the acetone-carbon bisulphide mixture on the rubber. This makes it possible to eliminate the extraction with chloroform and to determine free sulphur directly in the extract, provided the bisulphide is properly purified before use.

A large number of figures are presented to show the distinct advantage of the use of a mixed solvent over the separate extractions with acetone and chloroform, particularly in cheap compounds when the material is not all removed by the separate extractions.

THE DOUBLE POLARIZATION METHOD FOR THE ESTIMATION OF SUCROSE AND THE EVALUATION OF THE CLERGET DIVISOR.[10]

By Richard F. Jackson and Clara L. Gillis.

[ABSTRACT.]

A SINGLE polarization of a sugar mixture fails to give an exact indication of the quantity of sucrose since the observed

[9] Technologic Paper No. 162.

[10] Scientific Paper No. 375.

rotation is but the resultant of the rotations caused by the individual constituents. Hence since we are concerned with two unknown quantities, namely the rotation of sucrose and the rotations of all other substances collectively, it is necessary to construct two equations. In the Clerget method one equation states that the direct polarization is the sum of the rotations of sucrose and the impurities; the other states that the invert polarization is the sum of the rotations of inverted sucrose and the impurities. It is therefore essential to know the change of rotation of sucrose before and after inversion and to be sure that the rotations of the impurities remain unchanged in the two polarizations. The value of the change of rotation of sucrose before and after inversion, which is known as the Clerget Constant, was found by Herzfeld [11] to be 132.°66 S if all readings are taken at 20° C.

In the present investigation the velocity of inversion of sugar and its dependence upon temperature and concentration of hydrochloric acid was measured by starting the reaction quickly and arresting it abruptly by neutralizing the acid. By use of special apparatus to accomplish rapid mixing of the reagents, it was possible to measure velocity to an extreme temperature of 90° C. and for time intervals as low as thirty seconds. The knowledge obtained in these experiments enabled us to determine the length of time necessary at each temperature to produce 99.99 per cent. inversion of sucrose. In an analytical process it is not feasible to carry out the inversion at a constant temperature, consequently the above described method was used to determine the progress of the inversion under the prevailing conditions of analysis. In Herzfeld's method the sugar solution is acidified at room temperature and is heated rapidly to about 69° C. for a total time of seven and one-half to ten minutes. We have found that four and one-half to five minutes is sufficient. There is thus a period of about five minutes in which the acid may act on the products of inversion and may cause a diminution of negative rotation. We have measured the rate of decomposition at various temperatures and found it large enough to be the cause of considerable error in analysis. A temperature of 60° C. in the presence of 5 ml concentrated HCl for a total heating period of nine minutes is much more suitable.

Applying the conditions most suitable for obtaining com-

[11] *Zeit. Ver. Zuckerind.* 38, p. 699, 1888.

plete inversion and for avoiding decomposition of invert sugar, we have found by a series of eight concordant experiments that the Clerget Constant should be 133.25 at 20° C. instead of 132.66 as found by Herzfeld. This value is the algebraic difference of two quantities, +100°, the rotation of 26 g of pure sucrose, and −33.25, twice the rotation of 13 g of sucrose inverted by 5 ml of concentrated HCl, both solutions being made up to 100 ml and observed at 20° C.

The next question concerns the constancy of rotation of impurities in the two polarizations. If invert sugar is present in the original material, its rotation is observed in neutral solution for the direct polarization and in acid solution for the invert polarization. The effect of acid on the rotation of invert sugar was measured and found to be expressed by the formula:

$$R = -32.00 - 0.125\,C$$

in which C represents the number of ml of 1 : 1 HCl contained in 100 ml of solution. There is thus a change of rotation upon acidification which in analysis is reported as sucrose. A study of the effect of other reagents showed that an equal weight of salt produced the same effect. The error is thus corrected by the addition of salt to the solution for direct polarization.

The above formula gives for the rotation of invert sugar in aqueous solution −32.00 which is exactly the value obtained by Browne [12] by inverting sucrose with invertase. The same formula gives for the rotation of invert sugar in the presence of 18.18 ml of 1 : 1 HCl the value −34.27. Browne [13] reports −34.22. Our formula gives for 28.59 ml of 1 : 1 HCl the value −35.57. Steuerwald [14] reports −35.58. Thus our formula correlates satisfactorily four widely separated points on a curve. Herzfeld's value −32.°66 lies 0.°6 away from this curve.

We have moreover determined the rotation of invert sugar in the presence of 10 ml 1 : 1 hydrochloric acid neutralized by ammonia (−33.91) and by sodium hydroxide (−34.02).

Four modifications of the Clerget Method have been proposed which are adaptable to the various types of sugar products. These methods and comprehensive tables are given in full in the extended article.

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[12] *J. Assoc. Off. Agr. Chem.* 11, p. 140, 1916.

[13] *Ibid.*, p. 136. Browne reports —34.9 for 23.64 g of sucrose. This becomes —34.22 for 13 g multiplied by 2.

[14] *Archief.* 21, p. 831, 1913. *Int. Sug. J.* 15, p. 489, 1913.

NOTES FROM NELA RESEARCH LABORATORY.*

COLOR MATCH AND SPECTRAL DISTRIBUTION.

By Edward P. Hyde and W. E. Forsythe.

When two different radiators such as a tungsten and a carbon lamp are color-matched, *i.e.*, adjusted so that the integral color is the same, there has been some question as to the extent to which they have the same distribution of energy in the visible spectrum. This was tested out by one of the writers some years ago for carbon, tungsten and tantalum for a single temperature in the neighborhood of about 2160° K., and evidence was found that when the radiation intensities were set relatively equal at the two ends of the visible spectrum there was a difference at the centre of the spectrum of about one-half per cent. between a tungsten and carbon, and about twice this difference between carbon and tantalum. If two radiators have the same spectral distribution when they are color-matched, they can be brought to the condition for color-matching by measurements on the relative intensities of two spectral regions in different parts of the spectrum. Using an optical pyrometer first with a red, then with a blue glass screen before the eyepiece, four different radiators—a black-body, tungsten, tantalum, and untreated carbon—were set at the same relative intensity in the red and blue parts of the spectrum for several different temperatures. Measurements were then made with the pyrometer, using a green glass screen to see if the four radiators when thus matched in the red and blue were also matched in the green. It was found that if these four radiators were color-matched by determining the temperature for which the ratio of the red intensity to the blue intensity was the same, then the ratio of the red to the green was not what it should be if they had the same spectral distribution when they were thus color-matched. Taking the black body as the standard, the untreated carbon was found to be the same within experimental errors. The ratio of red to green for tungsten differed from that of a black body by about one-half per cent. for a temperature of about 1500° K. to about eight per cent. for a

* Communicated by the Director.

temperature of about 2900° K. For tantalum this difference was very nearly constant for a range in temperature from 1500° K. to 2700° K. and was equal to about 6 per cent.

THE GOLD-POINT PALLADIUM-POINT BRIGHTNESS RATIO.

By Edward P. Hyde and W. E. Forsythe.

IN a paper on "The Effective Wave-Length of Red Glasses," published in the *Astrophysical Journal* in November, 1915, appeared a note on some results on the gold-point palladium-point brightness ratio. This data was obtained by measurements with an ordinary disappearing-filament optical pyrometer with a red glass in the eyepiece.

Since that time additional data have been obtained by the same method. In addition some data have been taken on this ratio by means of a spectral pyrometer. In the work on this ratio several different black-body furnaces have been used. The sample of gold or palladium that was melted inside the black-body furnace was mounted between platinum wires supported by two porcelain tubes in such a manner that the central part of the sample could not touch either of these two tubes. This mounting was necessary as it has been found that if a single tube is used, sometimes the metal will touch and cling to the end of the tube so that the electric current through the two platinum wires and the sample used to give a signal when the sample melted would not be broken at the instant of melting and thus a high value would be obtained. In the table are given the results of measurements on the ratio.

SUMMARY OF RESULTS OF MEASUREMENTS OF THE GOLD-POINT PALLADIUM-POINT BRIGHTNESS RATIO.

Method	Number of Separate Determinations	Number of Melts Pd.	Number of Melts Au.	λ	Average of Ratio Found	Result for the Palladium Point
Ordinary pyrometer	10	45	45	0.6663	76.9	1828.6°K
Spectral pyrometer	3	13	12	0.6018	122.2	1828.3°K

The values for the palladium point were calculated from the ratios found, from the value of 1336° K. for the gold point and from $c_2 = 14350\mu$ deg. The range of values for the ratio found by means of the ordinary optical pyrometer is from one per cent. above to the same amount below the mean value given in the above

table. This range in the ratio corresponds to about one-twelfth of one per cent. in the value for the melting point of palladium. Thus the range due to this error is about $\pm$ 1.5° K. The range for the values using the spectral pyrometer was about the same, being in this case, somewhat less than one per cent. As a result of this work the Laboratories of the General Electric Company have decided, for the time being, to accept 1828° K. as the palladium point.

Alcoholic Fermentation in the Presence of Calcium Carbonate.—JOHANNES KERB (*Berichte der deutschen chemischen Gesellschaft,* 1919, lii, 1795–1800) has permitted both top yeast and bottom yeast to act on an aqueous solution of sucrose (cane sugar) and inorganic nutrient salts, to which calcium carbonate had been added. Both varieties of yeast produced a normal yield of alcohol. An insignificant increase occurred in the amount of acetaldehyde and of volatile acids, chiefly acetic acid. Not even traces of pyroracemic acid could be found. Alcoholic fermentation of sugars like glucose $C_6H_{12}O_6$ may be explained by formation of pyroracemic acid $CH_3COCOOH$, conversion of the latter into acetaldehyde CH_3CHO by loss of carbon dioxide CO_2, and reduction of the aldehyde to ethyl alcohol CH_3CH_2OH. However, calcium pyroracemate, like the free acid, is fermentable; this probably accounts for its failure to accumulate even though calcium carbonate was present to neutralize the pyroracemic acid as soon as formed.

J. S. H.

Action of Certain Organic Accelerators in the Vulcanization of Rubber.—G. D. KRATZ, A. H. FLOWER, and COLE COOLIDGE (*Journal of Industrial and Engineering Chemistry,* 1920, xii, 317–324) have reached the following conclusions in a research on this subject. The action of certain compounds, such as diphenythiourea, as accelerators is due to their tendency to decompose at the temperature and under the conditions of vulcanizing into simpler compounds which contain an active nitrogen group; the latter is responsible for the acceleration. The same accelerating action is exerted by equimolecular quantities of compounds which contain the same active nitrogen group in their primary nucleus. The accelerating action of the parent compound is decreased when hydrogen in the active nitrogen group is replaced by other and larger groups or radicals. The activity of the nitrogen is ascribed to a change in its valence from three to five with the temporary addition of sulphur; the active nitrogen group, therefore, functions as a sulphur-carrier.

J. S. H.

Forest Products Laboratory Decennial Celebration.—Preliminary arrangements are well under way for the observance at Madison, Wisconsin, during the latter part of June of the tenth anniversary of the opening of the Forest Products Laboratory. A large gathering of representatives from the various industries interested in the laboratory's work will be present and opportunity will be afforded for becoming more familiar with the extent and significance of its activities. Present plans call for a two-day meeting, with addresses by men of national reputation in science and industry, tours of inspection through the laboratory, informal discussions, and various forms of entertainment.

The Forest Products Laboratory is a branch of the United States Forest Service, established in 1910 in coöperation with the University of Wisconsin, and is a consolidation of a number of testing laboratories and other units of the Forest Service which had been located at various points throughout the United States. It is engaged principally in industrial research on problems connected with the manufacture and use of forest products, including besides lumber, posts, poles, ties, and similar products, pulp and paper, naval stores, hardwood and softwood distillation products, and other chemicals and pharmaceuticals. At the present time the laboratory employs about 200 people and occupies five buildings in whole or in part.

R.

Aniline Poisoning.—MAX NASSAUER (*Zeitschrift für angewandte Chemie,* 1919, xxxii (I), 333–335) states that a malignant tumor or cancer of the bladder occurs as an occupational disease among workmen who are exposed to the vapors of aniline. During a period of twenty-three years, from 25 to 30 per cent. of the tumors of the bladder, which came to operation at the surgical clinic of the University at Frankfurt am Main, were caused by aniline. The vapors of aniline are inhaled highly diluted with air; their effect on the bladder is slowly cumulative; the first symptoms of the cancer appear, on the average, when the workman has been employed in the factory for sixteen years. In order to reduce the danger to a minimum, the plant must be constructed of impervious materials and be amply ventilated; the evolved gases must be purified before their escape into the atmosphere; closed apparatus must be used; liquid raw materials and products must be handled with compressed air, solids by mechanical devices. Ample bathing facilities must be provided and used at the end of each day's work. Clean work clothes and wooden shoes must be worn daily, and gas-masks and rubber gloves must be used when necessary. The urine of the workmen should be examined at frequent intervals.

J. S. H.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

THE CONSTITUTION OF CAPSAICIN, THE PUNGENT PRINCIPLE OF CAPSICUM, II.[1]

By E. K. Nelson.

[ABSTRACT.]

SINCE the appearance of the author's first communication on this subject,[2] Lapworth and Royle[3] have published the results of their work on capsaicin.

As Lapworth and Royle are not fully disposed to accept the constitution of capsaicin as stated, further confirmation of its structure was sought in the regeneration of capsaicin. This synthesis was successfully accomplished, and the capsaicin formed found to be in all respects identical with the natural substance.

Synthetic vanillyl octoyl amide was found to resemble capsaicin closely in its stability toward boiling concentrated sodium hydroxide solution, and in its solubility in concentrated hydrochloric acid.

The decenoic acid isolated from capsaicin was found to yield, when fused with potassium hydroxide, acetic acid and octoic acid with a branched chain.

A PINK YEAST CAUSING SPOILAGE IN OYSTERS.[4]

By Albert C. Hunter.

[ABSTRACT.]

AN investigation of the cause of the pink color which develops in oysters during shipment was conducted on Narragansett Bay and in the oyster houses of Rhode Island. The organism responsible for the pink color was studied in detail, with the object of preventing its introduction into shipments of oysters. The results of this investigation are, in part, as follows:

* Communicated by the Director.

[1] Published in *J. Am. Chem. Soc.*, 42, 597–9 (1920).

[2] *J. Am. Chem. Soc.*, 41, 1115 (1919).

[3] *J. Chem. Soc.*, Trans., 115, 1109 (1919).

[4] *U. S. Dept. Agr. Bull.* 819, issued March 10, 1920.

The organism causing a pink color in oysters is a yeast-like fungus found in large numbers in and about the oyster house, and occasionally present in oysters before being brought to the oyster house. About 3 per cent. of the samples of water from the oyster beds showed the presence of the pink yeast which, however, was never recovered from mud samples from the bottom of the bay.

Tests for acid, gas, alcohol, indole and phenol were negative. The yeast inverts saccharose and reduces nitrates to nitrites and ammonia. It produces a pink pigment which is insoluble in water, slightly soluble in alcohol and carbon disulphide, somewhat more soluble in chloroform, and very soluble in ether. Formaldehyde gas, 1 part to 2500 parts of water, kills the yeast.

The greater part of the contamination of oysters with the pink yeast occurs during the process of handling in the oyster house. The shell pile of the opening house offers the yeast a favorable place to grow, and when the shells are later deposited on the oyster beds they distribute the yeasts in the water.

To prevent the infection of opened oysters by the yeast, the house and utensils should be washed occasionally through the opening season with a 1 to 2500 formaldehyde solution (formalin 1 to 1000).

PURIFICATION OF BENZOIC ACID BY FRACTIONAL CONDENSATION.[5]

By Max Phillips and H. D. Gibbs.

[ABSTRACT.]

BENZOIC ACID, made by the chlorination of toluene, is contaminated with small amounts of compounds chlorinated in the ring, the presence of which is most objectionable from the physiological point of view when benzoic acid is used in food products. While it is very difficult to remove these compounds by the ordinary methods of purification, benzoic acid practically free from chloro-derivatives was obtained in the Bureau of Chemistry by the use of a special apparatus. This apparatus consisted of a vessel in which the crude benzoic acid was placed. The vessel was immersed in an oil bath kept at a definite temperature. A blast of hot air was passed into the crude benzoic acid and the

[5] Published in *J. Ind. Eng. Chem.*, 12, 277 (1920).

vapors coming off were conducted through a series of chambers, maintained at different temperatures. The least volatile chloro-derivatives separated out in the hotter chambers, whereas the more volatile benzoic acid collected in the colder chambers.

SOME ASPECTS OF THE BEHAVIOR OF CHARCOAL WITH RESPECT TO CHLORINE.[6]

By G. S. Bohart and E. Q. Adams.

[ABSTRACT.]

THIS investigation was undertaken to determine the cause of discrepancies between results obtained by different laboratories for the chlorine capacity of the same charcoals. To study the effect of temperature and humidity of the air stream with which the chlorine was diluted (usually 1 : 1000), mixtures of known air, chlorine, and moisture content were passed through the charcoal which was held in a glass chamber in a constant temperature bath. The chlorine and hydrochloric acid in the outgoing gas were determined from time to time.

In the particular series of charcoals studied, the variation in chlorine-absorbing power between different charcoals was greater than would result from any attainable variation in humidity, and the order of the charcoals with respect to absorptive power is not the same as that with respect to apparent density.

The duration of complete chlorine absorption (1) increases more rapidly than the thickness of the layer of charcoal, (2) passes through a minimum at a temperature between 0° and 12.5°, and (3) at a humidity in the neighborhood of 50 per cent., and (4) is diminished by increasing the flow of air, the rate of supply of chlorine remaining constant. Reductions in pressure up to two feet of water (barometric pressured down to 71 cm. mercury) has little or no effect.

For the charcoals studied: Below 12.5° chlorine appeared beyond the charcoal before hydrogen chlorid; above 12.5° hydrogen chlorid before chlorine, and the chlorine capacity of the charcoal was increased by one exposure to chlorine followed by heating in vacuo to dull redness.

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[6] Published in *J. Am. Chem. Soc.*, **42**, 523–44 (1920).

Borax as a Plant Poison. (*Department. Cir. 84, U. S. Dept. of Agriculture.*)—The cessation of potash imports upon the oubreak of the war gave great impetus to search for domestic sources of the substance. Current topic notes in recent issues of this JOURNAL have furnished some of the interesting data on these new industries. Among the sources operated on a rather large scale was that of Searles Lake, California, from which many tons were taken. In 1917 injurious effects were produced by some fertilizers of domestic manufacture and it was found that borax was the cause of this. Investigations were undertaken, and in 1918 Professor Conner of the Indiana Agricultural Experiment Station published a report which attracted considerable attention, as it showed that very small amounts of borax can produce poisonous effects on maize. This seems to be the first record of such action, and of the occurrence of borax in appreciable amounts in a commercial fertilizer. Conner's conclusion was that a fertilizer containing 2 per cent. of borax in the proportion of 100 pounds per acre will cause damage to maize. The United States Department of Agriculture began in 1919 experiments with Searles Lake potash, which was found to contain 6.25 per cent. of $Na_2B_4O_7$. This potash was used in complete fertilizers in such proportion as to give from 2 to 8 per cent. of K_2O, and was compared with potash from other sources. The experiments were carried out with potatoes in the northern and some southern states and with cotton in other states. While these experiments were in progress, complaints were received in large numbers from different districts stating that great injury was being done by potash fertilizers. Investigations in these districts showed that in all cases borax was present. The damage was greatest when the fertilizer had been drilled in with the seed, and more severe when soil and climatic conditions were such as to cause the fertilizer to remain long in contact with the seed or the recently sprouted form. The greatest damage was done to germination. In the case of the potato the affected plants showed characteristic conditions which cannot be mistaken for any form of disease and which are fully described in the circular. It is not thought likely that permanent damage has been done to fields thus poisoned, as rainfall among other conditions will gradually remove the borax, but if fertilizers containing this substance continue in use, it will be incumbent upon those engaged in fertilizer investigation to determine the possible cumulative effect. The quantity of borax sufficient to produce decided toxic effects is small compared with well-known poisons such as copper and arsenic. The Searles Lake company is now turning out potash salts with less than one-half of one per cent. of borax.

H. L.

NOTES FROM THE U. S. BUREAU OF MINES *

BLOW HOLES, POROSITY AND UNSOUNDNESS IN ALUMINUM ALLOY CASTINGS.

By Robert J. Anderson.

It is impossible to compile a code of directions which a melter can follow implicitly and obtain 100 per cent. of sound castings. The main conclusions that can be drawn from experimental study are:

1. The higher the pouring temperature the greater the number of blowholes and the more unsound the casting.

2. The higher the temperature to which the charge is heated the more unsound the castings are, regardless of the pouring temperature.

3. The longer any melt is held in the furnace the more unsound the castings are, regardless of the temperature of heating and pouring.

All possible combinations of these three may be obtained, ranging from the worst result where pouring is done at a high temperature after the charge has been held a long time in the furnace at a high temperature, to the best where pouring is done at a low temperature from a charge held the minimum time after it has melted. There is no evidence to justify a belief that unsound castings result from too low a pouring temperature. The best results will be obtained through a close supervision of melting and pouring, together with a study of the appropriate correlation between the molding floor and the furnace room. It will be best to have the molding floor waiting for metal rather than the furnace room waiting for molds. Close pyrometric control is also presupposed. The details of experimental investigations on which these conclusions are based are given in Technical Paper 241 of the Bureau of Mines.

* Communicated by the Director.

MINOR NOTES

Gases in Tunnels.—In connection with the investigation of automobile exhaust gases in vehicular tunnels, which is being made at the Pittsburgh station in coöperation with the New York and New Jersey Tunnel Commission, a test made on a roadster with different carburetor settings while running 15 miles per hour uphill with three passengers, showed that the carbon monoxide produced at 60°F. ranged from 2 per cent. at 1¼ turns of the needle valve to 11.6 per cent. carbon monoxide at 1¾ turns of the needle valve. This corresponded to 13.9 and 8.73 miles per gallon of gasoline respectively. The car did not exhibit the necessary flexibility at one turn of the needle valve, which gave 1.2 per cent. carbon monoxide and 14.9 miles per gallon, the air on the carburetor being choked one-half. Slight changes in the adjustment of the carburetor affect the composition of the exhaust gases very materially, and greatly affect the mileage per gallon of gasoline consumed.

Evaporation of Oil.—A study of evaporation losses of oil in storage and transportation in the mid continent field has been completed and is being prepared for publication. The bulletin will point out clearly the loss in quantity of crude oil and gasoline and in dollars and cents, giving instances of just where these losses occur under the ordinary methods of handling the oil from the well to the refinery.

Petroleum from Oil Sands.—A study of problems relating to increased recovery of petroleum from oil sands has been started at the Bartlesville station of the Bureau.

Marine Boiler Tests.—The boiler tests made for the Emergency Fleet Corporation at Erie, Pa., have been completed. These tests indicated that relatively simple modifications of the design of marine boilers would enable six tons of coal to do the work of seven.

Graphite for Crucibles.—A study of the use of American Graphites in Crucible making by Dr. Reinhardt Thiessen, of the Pittsburgh Station, indicates that American graphites are composed of innumberable very thin plates. These plates are grouped into natural orders, by means of natural cleavage planes. These orders may conveniently, though perhaps not strictly, be classified as primary, secondary, tertiary and quarternary, each

order being determined by primary, secondary, tertiary and quarternary cleavage planes.

The flakes as they are found in the rock contain one or more cleavage planes along which the several plates are held together very loosely, and through a slight agitation or effort they may divide into two or more distinct flakes. This would constitute the secondary groups. Each of the secondary groups in turn contain one or more, usually several, natural cleavage planes, along which the plates hold together relatively loosely, but more firmly than the primary, along which they may be separated or loosened up by mechanical means, into tertiary groups of plates. At a higher magnification of a cross-section of the flakes, it is found that the tertiary groups again contain cleavage planes, tertiary planes, dividing them in turn with quarternary laminations. These orders of laminations are so thin that they can not be separated by mechanical means. The quarternary laminations are in the neighborhood of one micron in thickness.

In puffed graphite, however, they have been separated. By transforming graphite into graphitic acid, it is shown that the quarternary laminæ consist further of a series of sublaminations. The ultimate plates are of submicroscopic thickness, probably in the neighborhood of 50 to 150 millicrons.

The various methods employed to separate the graphite from the gangue divides the original flakes more or less into thinner flakes along the primary and secondary cleavage planes, or loosens them up along these planes as well as along the tertiary planes. This results in a fluffy, incoherent flake.

Photosensitiveness of Thallium Chloride.—CARL RENZ (*Helv. Chim. Acta.*, 1919, vol. ii, 704) describes a series of experiments showing that thallium chloride (TlCl) is affected by light, indicated by color changes in the order gray brown, dark gray brown, and brownish black. The changes are largely molecular, but some subchloride is also formed. Hydrochloric acid even in minute amounts prevents the action, as also do sulphuric and nitric acids. Ammonia, ethylamin and a large number of organic liquids and many inorganic salts act as sensitizers. The sensitiveness of the salt is influenced by the method of preparation. Specimens prepared by precipitation of thallium solution with metallic chlorides are much more sensitive than that prepared by precipitation with hydrochloric acid, even when this is thoroughly washed.

H. L.

The Height of the Aurora Borealis as Determined at the Haldde Observatory, Norway. L. VEGARD and O. KROGNES. (*Annalen der Physik,* vol. li, 1916.)—If the aurora is photographed at the same time from two stations it is possible, as Stoermer has shown, to get the height of any characteristic feature appearing on both plates from its two different positions with respect to the stars. The stations must have telephonic connection. Those by means of which the greatest number of determinations have been made are 26.3 km. apart.

The upper boundaries of the auroras vary from 100 to 330 km. above the earth, and are usually indistinct. They are highest for rays and lowest for arches. The lower boundaries are clearly defined. No less than 1920 measurements of height are divided into six groups, according to the forms assumed by the aurora and the average height is calculated for each class. It is remarkable how closely these average heights of the lower boundaries are grouped together between 104 and 114 km., the general average being 108.2 km. When curves are formed by plotting the number of lower limits at a height against the height it is found that there are two maxima corresponding to heights of 100 and 106 km. respectively, which persist in showing themselves even when results from different pairs of stations are used for the curve.

G. F. S.

A New Method of Determining the Solar Constant of Radiation. C. G. ABBOT. (*Proc. of the National Academy of Sciences,* January, 1920.)—The method hitherto employed, that of Langley, consisted in measuring the intensity of solar radiation at the earth's surface and then of determining the transparency of the atmosphere for all wave-lengths by the spectro-bolometer. The latter part required several hours during which the atmosphere should not have changed. At the Calama Smithsonian Station a new and faster method has been developed. The brighter the sky is and the larger the amount of water vapor in the air, the less is the atmospheric transmission. Quantities can be measured which are determined by brightness of sky and by content of water vapor. A function of these two quantities is formed and is plotted against air transmission coefficients, all the quantities involved being related to similar atmospheric conditions. It takes only ten minutes to make all the measurements needed to determine the function mentioned. When it has been determined, the transmission coefficient can be read off. Several radiation determinations can be completed in a single day, and besides this the new method can be applied on a greater number of days than the old one could.

G. F. S.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting held Wednesday, April 21, 1920.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 21, 1920.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership since last report, 7.

The following gentlemen, nominated by the Board of Managers, were unanimously elected to Honorary Membership: Sir Charles Algernon Parsons, K.C.B., C.B., M.A., LL.D., D.Sc., F.R.S., and Prof. Svante August Arrhenius, Ph.D., M.D., D.Sc., LL.D.

Reports were presented by the Committee on Library and the Committee on Science and the Arts.

The paper of the evening on "The Design of War Vessels as Affected by the World War" was presented by Rear Admiral David Watson Taylor, Chief Constructor, U. S. N., Chief of Bureau of Construction and Repair, Navy Department, Washington, D. C. A description was given of the various types of vessels existing at the beginning of the war and the improvements and changes made or shown to be desirable during the progress of the war. The question of new types of war vessels growing out of war experience was also discussed. Lantern slides of various classes of war vessels of several countries were shown.

After a vote of thanks to the speaker the meeting adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, April 7, 1920.)

HALL OF THE INSTITUTE,
PHILADELPHIA, April 7, 1920.

MR. CHARLES PENROSE *in the Chair.*

On the recommendation of the Sub-Committee on Literature, the following awards were made for papers in the JOURNAL, 1919:

No. 2757: The Edward Longstreth Medal of Merit to Mr. M. Luckiesh, of the Nela Research Laboratory, Nela Park, Cleveland, Ohio, for his paper entitled: "The Visibility of Airplanes," which appeared in the issues of the JOURNAL OF THE FRANKLIN INSTITUTE for March and April, 1919.

No. 2758: The Certificate of Merit to Messrs. David Landau and Percy H. Parr for their series of papers on "A New Theory of Plate Springs," which appeared in the JOURNAL OF THE FRANKLIN INSTITUTE for April, 1918, December, 1918, and February, 1919.

The following reports were presented for first reading:

No. 2746: Method of Machining Propeller Blades.

Mr. Charles W. Masland, Chairman.

No. 2747: Concealing Coloration.

Dr. Thomas D. Cope, Chairman.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A joint meeting of the Section and the Physics Club of Philadelphia was held in the Hall of the Institute on Thursday, April 1, at 8 o'clock, P.M. Dr. Thomas D. Cope in the Chair. The minutes of the previous meeting were approved as read.

Charles E. Mendenhall, Ph.D., Professor of Physics in the University of Wisconsin, delivered a lecture on "Aeronautical Instruments." A description was given of the standard instruments used for the determination of height, speed and engine performance, and for the navigation of the airplane. Mention was also made of instruments which are being developed for these purposes. The lecture was illustrated with lantern slides.

The paper was discussed; a rising vote of thanks was extended to Doctor Mendenhall, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Electrical Section.—A joint meeting of the Section and the Philadelphia Section, American Institute of Electrical Engineers, was held on Thursday evening, April 8, 1920. Mr. W. C. L. Eglin and Mr. W. F. James presided jointly.

The paper of the evening on "Electric Welding as Applied to Shipbuilding" was presented by Comfort A. Adams, S.B., E.E., Dean of the Harvard Engineering School, Harvard University, Cambridge, Mass. The speaker reviewed the theory and practice of electric welding, including resistance welding, spot welding, and arc welding. The strength and other physical properties of electric welds were considered, as well as the application of electric welding in the industries. An account was given of past experience in the use of electric welding in shipbuilding, with some indications of its future prospects. Attention was also given to the design and construction of welded ships. The subject was illustrated by lantern slides.

After a vote of thanks to the speaker the meeting adjourned.

ALFRED RIGLING,
Acting Secretary.

Mining and Metallurgical Section.—A joint meeting of the Section and the Philadelphia Section of the American Chemical Society was held in the Hall of the Institute on Thursday evening, April 15, at 8 o'clock, with

Prof. Alexander E. Outerbridge, Jr., in the Chair. The minutes of the previous meeting were approved as published.

D. A. Lyon, Ph.D., Bureau of Mines, U. S. Department of the Interior, Washington, D. C., delivered a lecture on "Recent Progress in the Metallurgy of Non-ferrous Metals." An account was given of recent advances in the winning of gold, silver, copper, lead, and zinc from their ores. The paper was discussed by Doctors Keller and Lyon, Professor Outerbridge and Mr. Clamer. On motion of Mr. Clamer, a vote of thanks was extended to Doctor Lyon for his valuable communication. The meeting then adjourned.

JOSEPH S. HEPBURN,
Acting Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, April 14, 1920.)

RESIDENT.

MR. SAMUEL G. DIXON, 2D, Marine Engineer, Montgomery Avenue, Ardmore, Pennsylvania.

DR. FRANKLIN G. HAWKSWORTH, Dentist, 314 N. 13th Street, Philadelphia, Pennsylvania.

MR. WALTER E. HOLLAND, Research Engineer, Philadelphia Storage Battery Company, Ontario and C Streets, Philadelphia, Pennsylvania.

MR. ROLAND G. PORTER, Gas Engineer, Swarthmore, Pennsylvania.

ASSOCIATE.

MR. FELIPE T. ADRIANO, Industrial Chemist, 102 N. Orchard Street, Madison, Wisconsin.

MR. F. MACMURPHY, Student, 301 West 108th Street, New York City, New York.

MR. SAMUEL N. MORRISON, Manufacturer of Oil Dressings, 143 W. Lehigh Avenue, Philadelphia, Pennsylvania.

CHANGES OF ADDRESS.

MR. A. I. APPLEBAUM, P. O. Box 808, Trenton, New Jersey.

MR. J. VAUGHAN BOSTWICK, Roxborough, Philadelphia, Pennsylvania.

DR. M. E. COOLEY, Engineering Building, University of Michigan, Ann Arbor, Michigan.

MR. EDWIN FRANK, 5233 "A" Wissahickon Avenue, Germantown, Philadelphia, Pennsylvania.

MR. G. L. KOTHNY, Woodland Road, Strafford, Pennsylvania.

MR. H. H. MAXFIELD, General Superintendent, Motive Power, Pennsylvania System, Central Region, Pennsylvania Station, Pittsburgh, Pennsylvania.

MR. W. HEYWARD MYERS, Haverford, Pennsylvania.

PROF. C. C. THOMAS, Johns Hopkins University, Baltimore, Maryland.

DR. J. A. L. WADDELL, 35 Nassau Street, New York City, New York.

MR. J. R. WATKINS, 817 Oakbridge Avenue, Madison, Wisconsin.

NECROLOGY.

Carrol M. Bunting was born at Darby, Pa., on September 15, 1871, and died in Philadelphia on March 4, 1920.

He was educated at the Darby Friends School, the Philadelphia Public Schools and Bryant and Stratton's Business College.

In 1887 he became a clerk in the Freight Office at Philadelphia for the Chicago, Rock Island & Pacific Railroad Company. He then entered the office of the Through Freight Agent of the Philadelphia & Reading Railway, and later served in the Philadelphia Freight Office of the Northern Pacific and Wisconsin Central Company. In 1890 he became Secretary to the Third Vice President of the Pennsylvania Railroad Company. Seven years later he was made Chief Clerk to the First Vice President and in 1906 became assistant to the same official. He was appointed Assistant Comptroller on March 24, 1909, and in June, 1910, was made Comptroller.

Shortly after the United States entered the World War, Colonel Bunting obtained leave of absence and served as business manager of the Transportation Corps, American Expeditionary Forces. He was also a member of the staff of Brigadier General W. W. Atterbury, Director General of Transportation. He returned from France early in 1919, and had been in poor health since that time.

Colonel Bunting became a member of the Institute September 11, 1912.

Mr. John A. Brown, Jr., Real Estate Trust Building, Philadelphia, Pa.

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BOOK NOTICES.

DATA OF GEOCHEMISTRY. United States Geological Survey, Bulletin 695. By Frank Wigglesworth Clarke. 4th edition. 773 pages and index, 8vo. Washington, Government Printing Office, 1920.

This work comprehends an elaborate study of the materials constituting the earth as included in human experience; that is, the lithosphere and the atmosphere. A vast amount of information concerning the composition of rocks, waters and gases is presented in a readable and at the same time strictly scientific form. The literature has been searched thoroughly and with great care, and it is really astonishing to those who have not followed the special field to which the work is devoted to see the extent of the researches already carried out. There is a somewhat romantic feature of the essay, inasmuch as discussions are given concerning the age of the earth's crust, the origin of the atmosphere and the source of the great mass of carbon now locked up in the rocks which are so marked a feature of the crust as we know it. As might be expected, the discussions on these subjects do not lead to any positive result, although some of the promulgators of special views are quite convinced of the reliability of their conclusions.

Special note should be given to Doctor Clarke's method of presenting the composition of waters. Discarding the usual methods of uniting the several positive and negative ions into salts according to the arbitrary methods long in vogue, he recalculates the data into percentage of the ions, using the residue after ignition as the total fixed solids. It is, of course, an advantage to get rid of the so-called "loss on ignition," which

is so common in statements of water analysis, for the figure has neither practical nor theoretical value, but it is an open question whether the residue dried at a moderate temperature will not in many cases be a safer guide. The figure for the fixed solids is stated as "salinity," a word that may be not wholly satisfactory, as it seems to suggest the content of chlorides. Doctor Clarke's method of presenting the data of water analysis has the advantage of enabling quick and convenient comparison of waters of the same type and showing vividly the contrast between waters of different types.

It will be probably a long while before the commercial analyst will be able to make a statement of water analysis on the basis of the unassociated ions, for his clients always want a presentation that will show some of the specific actions of the sample. Even many scientific workers hesitate to set down Fe^{III} or SiO_3.

HENRY LEFFMANN.

AIDS IN THE COMMERCIAL ANALYSIS OF OILS, FATS AND THEIR COMMERCIAL PRODUCTS. By George Fenwick Pickering. viii—129 pages and index. 8vo. Philadelphia, J. B. Lippincott Company, 1917.

Not much new matter can be expected in a book of this size on a topic which has been so extensively exploited as that of the fats and oils, for the existing literature is immense. The work contains a great deal of information compactly presented, especially in tabular form. The methods chosen are mostly so-called "works methods," and do not claim such a degree of accuracy as is found in many departments of inorganic analysis. The author states that all the figures given are published for the first time. Mr. Pickering's position as a research assistant to the late Doctor Lewkowitsch is a guarantee that he has had large experience in careful work and is familiar with the field to which the book is devoted. The nomenclature is mostly conservatively English, and the determination of the volatile acids is given only by the alcohol-potassium hydroxide method, no mention being made of the glycerol-soda procedure, which is now official in France, Germany and several other leading European nations.

HENRY LEFFMANN.

THE PHOTOGRAPHIC RESEARCHES OF FERDINAND HURTER AND VERO C. DRIFFIELD, being a reprint of their published papers, together with a review of their earlier work and a bibliography of their later work. Edited by W. B. Ferguson, K.C., M.A. (Oxon.), F.I.C. Hon. F.R.P.S. Small folio, 366 pages, indexes, and numerous illustrations. London, The Royal Photographic Society of Great Britain, 1920.

The names of Hurter and Driffield are familiar to all photographers, and the Royal Photographic Society has done them just honor by thus presenting in full many of their papers and furnishing a bibliography for the rest. The apparatus and manuscripts are now in the custody of that society. A list of these is given, and shows a very large and varied collection.

Frederick Hurter was born in 1844 at Schaffhausen in Switzerland, and after studies at Zurich went to Heidelburg, where he studied under

Bunsen, Kirchoff and Helmholtz, and in 1866 he took the degree of Ph.D. "Summa cum laude." He spent the last thirty-one years of his life in England, for which he had a definite preference. He began his work there as an assistant to Mr. Deacon in the alkali works of Gaskell, Deacon & Co.

Vero C. Driffield was born in Lancashire. He was early interested in photography, but also entered into the service of Gaskell, Deacon & Co., as an engineer, and there met Doctor Hurter. It was, however, a mutual passion for music that led to the intimacy.

The book contains many data of great interest to photographers. Among the most comprehensive of the contributions is that published in 1898 on "The Latent Image and Its Devlopment," a joint contribution.

The book is excellently printed and will furnish much attractive reading to all interested in photochemistry.

HENRY LEFFMANN.

UTILISATION DES ALGUES MARINES. Par Camille Sauvageau. Professor in the Faculty of Science, Bordeaux. 12mo., 356 pages, bibliography, contents, indexes and 26 illustrations. Paris, Gaston Doin. 9 francs.

This work is one of a series designated "Encyclopédie Scientifique," which has a wide scope, a list of forty volumes being appended to the present publication. Its form is very pleasing, being printed on good paper with clear type, of a more agreeable face than that often used in French books. The coastal districts of Brittany and Normandy and some adjacent islands owe a good deal of prosperity to the marine algæ, which are used as fertilizers. In former years, the material was burned and sodium salts extracted; later potassium and iodine were the principal yields. During the late war proposals were made for the use of these plants as fodder, and even as human food, and the French Government through one of its bureaus requested M. Sauvageau to investigate the subject. His results, supplemented by his wide information on the botany and biology of the algæ, are embodied in the book. A great deal of information is contained in it, among which are to be noted the government regulations for the harvesting of the more important species, descriptions of the American methods of gathering, data regarding the composition and the uses that have been made as food for men and domestic animals. The illustrations are neatly drawn and the book will be useful to the cryptogamist, biologist and economist.

HENRY LEFFMANN.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS. Report No. 50. Calculation for low pressure indicator diagrams. Preprint from Fourth Annual Report. 13 pages, diagrams, quarto. Washington, Government Printing Office, 1920.

This report contains a theoretical study of the pressure variations in an internal combustion engine cylinder during the low pressure part of the cycle. It is assumed that the rate of flow of air and burnt gas through the inlet and exhaust valves, respectively, may be calculated from the manifold pressures, the cylinder pressure, and the valve clear openings

by the ordinary formulas for steady flow through an orifice with the aid of determinable coefficients of efflux. Differential equations for the rate of change of the pressure in the cylinder during the exhaust and suction strokes are set up. A method for the graphical integration of these equations is indicated. Efflux coefficients taken from the experiments of Lewis and Nutting are used in the application of the theory to a typical motor, and a theoretical low pressure indicator diagram for this motor is obtained.

Report No. 51. Spark Plug Defects and Tests. Preprint from Fifth Annual Report. 32 pages, illustrations, quarto. Washington, Government Printing Office, 1920. A discussion of the various causes of failure of spark plugs, with indications for their identification and possible remedies. The results of gas leakage measurements on several hundred plugs are given and the results tabulated on a basis of design, material, etc. The final chapter describes methods worked out for testing spark plugs in the laboratory for (1) electrical conductivity when hot, (2) resistance to thermal cracking, (3) gas tightness, (4) resistance to mechanical shock, (5) dielectric strength, (6) engine test.

Report No. 61. Head Resistance due to Radiators. Preprint from Fifth Annual Report. 22 pages, illustrations, quarto. Washington, Government Printing Office, 1920. The report gives detailed descriptions of apparatus, experimental methods, and methods of computation used in determining (*a*) head resistance, and (*b*) power absorbed due to head resistance and weight, for radiators in "unobstructed" positions on the airplane. Results obtained on 24 types are shown in tables and curves. Effects of yawing the radiator are shown for four representative types. A brief discussion of the importance of head resistance is given.

Curves show measured head resistance of a model fuselage under three conditions: (1) with stream-lined nose, (2) with flat nose, and (3) with nose radiator. Three widely different types of radiators were used.

A method of enclosing a radiator in a stream-line casing is described. but results show that, while head resistance may be reduced by the use of the casing, air flow through the core and heat transfer are decreased to such an extent as to lower the efficiency.

R.

PUBLICATIONS RECEIVED.

Royal Photographic Society of Great Britain: A memorial volume containing an account of the photographic researches of Ferdinand Hurter and Vero C. Driffield, being a reprint of their published papers, together with a history of their early work and a bibliography of later work on the same subject. Edited by W. B. Ferguson. 374 pages, illustrations, portraits, quarto. London, Royal Photographic Society of Great Britain, 1920. Price, 25 shillings.

Utilisation des algues marines, par Camille Sauvageau. Encyclopédie Scientifique. 394 pages, illustrations, 12mo. Paris, Octave Doin, 1920. Price, in cloth, 9 francs.

U. S. Bureau of Mines: Bulletin 95, A Glossary of the Mining and Min-

eral Industry, by Albert H. Fay. 754 pages, 8vo. Technical Paper 250, Metal-mine Accounting, by C. B. Holmes. 63 pages, 8vo. Technical Paper 252, Metal-mine Accidents in the United States During the Calendar Year 1918 (with supplemental labor and accident tables for the years 1911 to 1918, inclusive), compiled by Albert H. Fay. 113 pages, 8vo. Technical Paper 256, Accidents at Metallurgical Works in the United States During the Calendar Year 1918. Compiled by Albert H. Fay. 23 pages, 8vo. Washington, Government Printing Office, 1920.

U. S. Department of Agriculture, Weather Bureau: Daily River Stages at River Gauge Stations on the Principal Rivers of the United States. Volume XVI, for the year 1918, by Alfred J. Henry, meteorologist. 288 pages, quarto. Washington, Government Printing Office, 1919.

The Philadelphia Museums, The Commercial Museums. Hand-books to the Exhibits. No. 3, The Peat Exhibit. 56 pages, illustrations, 8vo. Philadelphia, The Museums, 1920. Price, 25 cents.

University of Illinois Convocation: The Watt Centenary and the College of Engineering Open House. 20 pages, illustrations, portrait, diagram, 8vo. Urbana, University, 1920.

U. S. Department of Labor, Bureau of Labor Statistics: Prices and Cost of Living. From the Monthly Labor Review, March, 1920. 52 pages, 8vo. Washington, Government Printing Office, 1920.

Two Years of Faulty Taxation and the Results, by Otto H. Kahn. 52 pages, 12mo. No place, 1920.

Pacific or 4-6-2 Type of Locomotive. Educational Chart No. 12. 44 x 16½ inches. New York, Railway and Locomotive Engineering, 1920.

Present-Day Radiography. MAJOR G. W. C. KAYE. (*Electrician,* Feb. 6, 1920.)—X-rays have been found to penetrate no less than 5 mm. of lead and for the protection of the operator 3 mm. of this metal are desirable.

Flaws, blowholes, bad welds, blisters and concealed riveting all are detected by radiography. At present the practicable thicknesses which can be investigated are three inches for steel and twice as much for aluminium.

During the war much use was made of the X-rays in examining the wooden parts of aeroplanes, especially the laminated parts. This method of construction enabled smaller timber to be used but also increased the difficulties of detecting faults. By the X-rays, however, bad gluing, grub holes, knots and bad workmanship were laid bare.

An interesting suggestion is made that this method of investigation be applied to growing timber to detect defects, the presence of nails, axe heads and internal shakes filled with mineral deposits, such as phosphates in teak.

At the Röntgen Society Exhibition in London radiographs of Dutch pictures of about 1500 A.D. were displayed. In one case an alteration was shown which consisted in painting a portrait of the donor upon the picture of a monk. G. F. S.

CURRENT TOPICS.

A New Method of Analysis.—Wm. Roy Mott, Research Chemist for the National Carbon Company, presented at the recent meeting of the American Electrochemical Society (April 8–10, 1920) a description of a carefully worked out method of detecting the several elements by means of the characteristics of the electric arc-action on compounds of these elements. The process is an extension of the method of flame tests, which method, as is well known, finds special development in the spectroscope. Mott's apparatus is, however, much simpler than the spectroscope, and his procedure rapid and accurate. The following data are taken from an advance publication of the proceedings of the American Electrochemical Society. The essential apparatus consists of a carbon arc-lamp in a hood, so arranged as to project a magnified image upon a screen in a dark room. Usually a magnification of twenty diameters is satisfactory, but for a few very dim arcs a lower power is advisable. The lamp is trimmed with solid carbons about 13 mm. in diameter, such as are commonly used in closed arc lamps. A cup about 10 mm. in depth and diameter is drilled into the top of the lower carbon, which is usually connected with the positive pole. The average weight of the sample used is 0.5 grm. Mott operated the lamp at 25 amperes and 50 (arc) volts, from a 110-volt line.

The phenomena obtained are flame-tip color, sparks, smoke, odor, sequence of distillation, and especially the nature and color of the deposit on the poles. A special vapor luminescence, near positive crater, is characteristic of some elements; for instance, calcium gives a unique red The colors of the flame tip above the arc are tests for sodium, lithium, boron and copper. Iron produces a display of scintillating sparks from the negative carbon for several seconds after breaking the arc. Smoke is not as a rule a delicate test, but the emission of smoke from the hot upper tip on breaking the arc is a very delicate test for molybdenum, as Mott has not found a similar effect given by any other element. The odor aids in detecting arsenic, bromine, iodine and tungsten. The color and shape of the deposit on the upper carbon are excellent points for classification. It is obvious that the method affords a form of fractional distillation at high temperatures, and of great range from mercury which boils at 257.2° C. to tungsten which boils at about 6000° C.

The new methods of analysis, using the arc images, are simple, quick, delicate, automatic, semi-quantitative and comprehensive. Good tests are given later for sixty-five elements. Any of these can be quickly and easily identified in a few minutes in their ores, alloys, oxy-compounds or in small, very impure samples. The chief impuri-

ties are usually automatically discovered as the distillation proceeds. In mixtures of three metallic compounds—especially oxy-compounds—complete identification should be obtained in less than a quarter of an hour. The tests, so far developed, will identify on the average nine out of ten in unknown mixtures of any ten of these sixty-five elements. Very delicate tests (sensitive to 0.1 mg.) apply mostly to the uncommon, valuable, and refractory elements, which take so much time and skill to identify by the usual wet methods. In regard to halogen salts, the best procedure is to form oxy-compounds by alkali carbonate fusion, or other means. The tests as given apply directly to all ores, minerals, refractories, oxides, oxy-compounds, carbides, metals and alloys.

Future developments should lead to an extensive use of arc image analysis, as it supplements and aids all other means of analysis. It is much like a refined blow-pipe analysis in utilizing colored beads and deposits. It is like fire-assay in using metal bead separations. It is like spectrum analysis in using colored light. Finally, it is like micro-chemistry in utilizing magnified phenomena. These similarities explain its comprehensiveness and indicate a large field for further study.

H. L.

Coke Industry in 1919. (*U. S. Geological Survey Press Bulletin No. 442,* April, 1920.)—The outstanding features of the coke industry in 1919 were the great slump in demand that followed the armistice and a remarkable increase in the proportion of by-product coke as compared with beehive coke.

The output of by-product coke consequently exceeded that of beehive coke for the first time. In 1918 about 46 per cent. of the total coke made in the United States was produced in by-product ovens and 54 per cent. in beehive ovens. In 1919 the proportions were reversed, 56 per cent. coming from by-product and only 44 per cent. from beehive ovens. The year 1919 thus marked a turning point in the history of coke manufacture in the United States.

These figures are preliminary only and will be revised when the annual statistical canvass is completed.

The iron furnaces are the great customers of the coke industry. With the growth in the output of by-product ovens the beehive coke industry is likely to become more and more an auxiliary source of fuel, carrying the peak load in times of extreme activity and correspondingly restricted in times of depression.

The maximum capacity of the by-product plants has been estimated at 27,000,000 net tons of coke at the beginning of 1918, 33,700,000 tons at the beginning of 1919, and 39,500,000 tons at the beginning of 1920. These annual capacities are estimated on a basis of 100 per cent. operation. In actual practice, however, an average operation above 90 per cent. can not be assumed for the country as a whole, and the safer figure of 85 per cent. would appear better justi-

fied by experience. Under an operation of 85 per cent. the present capacity of the country would be about 33,600,000 tons. Completion of the plants now under construction may raise the capacity to approximately 43,300,000 tons, or 36,800,000 tons under an operation of 85 per cent.

Estimated according to the quantity of by-product coke produced in 1919—25,171,000 tons—the quantities of by-products recovered during the year amounted to 668,200,000 pounds of ammonium sulphate or equivalent, 251,000,000 gallons of tar, 84,800,000 gallons of crude light oil, and 367,700,000,000 cubic feet of gas.

Some Studies of Metals by Means of X-rays. S. NISHIKAWA and G. ASAHARA. (*Phys. Rev.*, January, 1920.)—A pencil of heterogeneous rays from a Coolidge tube was received upon a photographic plate after having traversed a thin sheet of metal. Rolled metal gave a blurred pattern, but each metal had its own pattern. When the metal was annealed a considerable change of pattern followed, definite spots replacing the blurred figures. Silver and tin gave changed patterns after being kept at room temperature for some time. The disappearance of strain can thus be followed. Rolled thallium gave a figure consisting of spots arranged along radii. When it was heated to 235° C. suddenly a new pattern made its appearance. This is retained during further heating. Upon cooling another abrupt change manifests itself at the same temperature, but the resulting pattern is not the same as the first.

G. F. S.

Science and Its Application to Marine Problems. J. C. MCLENNAN, O.B.E. (*Trans. Northeast Coast Institution of Engineers and Shipbuilders.*)—In this very comprehensive and interesting paper it is stated that Sir J. J. Thomson suggested and D. A. Keyes applied to the study of the propagation of pressures caused by explosions under water the phenomenon that certain crystals become charged with electricity when subjected to pressure. As the amount of the charge is directly proportional to the pressure, measurement of the amount of the pressure is possible, but the problem is not easy, since the time it takes to crush a submarine is only a few thousandths of a second, while the pressure may be of the order of 1000 pounds per square inch. To record pressure changes a beam of cathode rays was deflected in one direction by an alternating magnetic field and in a direction perpendicular to the first by the electric field set up by the charge developed on the crystal by the pressure wave. Changes taking place in one one hundred-thousandth of a second can thus be traced. Valuable conclusions relating to the best methods of laying out mine fields and employing depth charges have been drawn as a result of Curie's recondite discovery of piezo-electricity.

G. F. S.

Carbon Determination in Ferro-alloys.—C. J. ROTTMANN, Advance Sheets, *Amer. Electrochem. Soc.*, Thirty-seventh General Meeting, April 8–10, after pointing out the difficulties of correct determination of carbon in these alloys, describes construction of furnaces, absorption bulbs, and methods by which accuracy to 0.002 per cent. can be attained. Minute directions are given for taking the sample. The furnace is nichrome wound, and a thick-walled silica tube is to be used, as thin tubes become penetrable above 1200° C. The special form of the absorption bulb is figured, and is stated to be light, compact, and easily handled. A comparatively large amount of liquid may be used, thus allowing many runs without refilling. The test-analyses given with samples from Bureau of Standards are very satisfactory.

H. L.

Bronze Plating. (Advance sheets of paper to be presented at the Thirty-seventh General Meeting of the American Electrochemical Society, April 8–10.)—F. C. MATHERS and STANLEY SOWDER detail experiments to determine the practicability of depositing copper-tin alloys electrically, and find this possible under certain conditions. Bennett (*Trans. Amer. Elec.-chem. Soc.*, 1913, vol. xxiii, 255) collected data for all the bronze-plating baths so far described and found them practically all unsatisfactory. Commercially, bronze color is imitated with brass or coloring by a reagent. Some German investigators obtained satisfactory results for a time with a bath containing copper sulphate, sodium hydroxide, stannic chloride, and sodium tartrate, but it soon became useless.

Mathers and Sowder experimented with a bath constructed as follows: Two anodes (90 per cent. copper and 10 per cent. tin) 4 by 4 cm. were used in each bath, the content of which was 200 c.c. The single cathode in each was 4 by 4 cm., and the temperature 40° to 50° C., the current density 0.4 ampere per square decimeter. A decrease of current density caused increase of deposition of the more easily separated ingredient, which separability, however, differed with the composition of the bath, copper separating more readily from the oxalate bath and tin from the cyanide-stannate bath.

The following solutions were used:

Oxalates.—Ammonium oxalate, 5.5 per cent.; copper sulphate, 1.5 per cent.; stannous oxalate, 0.42 per cent.; oxalic acid, 0.5 per cent. gave a bronze deposit for a short time, but soon the only result was a hard brittle copper, due to poor corrosion of the anodes. As 5.5 per cent. ammonium oxalate will dissolve much more of the two metals than the quantity used at first, tests were made with more concentrated solutions, but satisfactory deposition was not obtained. After many experiments, the following method was found serviceable: A 500 c.c. bath containing 6 per cent. ammonium oxalate, 2 per cent. copper oxalate, 1.6 per cent.

ammonium citrate, 1.2 per cent. potassium sulphate, and 0.4 per cent. citric acid was electrolyzed with copper anodes. Fifty c.c. of the solution was removed and strips of pure tin inserted, whereby copper was precipitated and tin dissolved. Every few hours this treatment was repeated and the previous portion was filtered and returned to the bath. In this manner the ratio between the metals was kept fairly constant. One of these baths was maintained in efficient operation for two months.

Cyanides.—Good deposits were obtained from a bath containing potassium hydroxide, 5 per cent.; potassium cyanide, 0.2 per cent.; stannic ammonium chloride, 0.38 per cent.; and potassium copper cyanide, 1.5 per cent. The bronze anodes remained bright and free from slime, but for several days only copper was deposited, which action the authors believe to be due to the necessity for reduction of the stannic to the stannous condition. The use of much free cyanide decreases the rate of copper deposition and gives tin-colored coating. The current density and temperature used for the above bath were the same as those for the oxalate bath.

H. L.

Artificial Abrasives.—The manufacture of artificial abrasives —silicon carbide and corundum—in the electric furnace is described by C. J. BROCKBANK (*Journal of the Society of Chemical Industry, Transactions,* 1920, xxxix, 41–43). For silicon carbide or carborundum, electric furnaces with a capacity of 1000 to 3000 horsepower are used; the yield per unit of power is somewhat larger in the largest furnace, but the product is somewhat inferior in quantity to that made in the smallest furnace. The 1000 horsepower furnace has an inside width of 5 or 6 feet, and a length of 20 feet between the heads which carry the electrodes. These heads are 40 inches thick. Each terminal has two electrodes of graphite, 10 inches in diameter and 48 inches long. A resistor core of 1200 pounds of graphite powder is placed between the electrodes; it forms a layer 36 inches wide and 10 inches deep, and carries the current. The charge lies below, above, and on both sides of this core. A typical charge, using new materials, contains 1500 pounds petroleum coke, 2520 pounds white sand, 300 pounds sawdust, 40 pounds salt. The sawdust is used to make the mass porous, facilitate escape of the carbon monoxide formed in the reaction, and prevent formation of blowholes. The salt aids in the elimination, as chlorides, of impurities present in the sand and coke. The entire charge is not converted into carborundum; a portion merely serves as a heat-insulating blanket. This unused portion is added to the next charge which has the following composition: Petroleum coke, 1500 pounds; sand, 2455 pounds; sawdust, 300 pounds; old mixture, 400 pounds; salt, 40 pounds. The furnace is run at a voltage between 85 and 160, usually 85 and 100, for a

period of thirty-two to thirty-four hours. Each pound of crystalline carborundum produced requires 5 kilowatt-hours of electric energy. The crystalline product is removed from the furnace after cooling, is crushed, treated with sulphuric acid, and then with caustic soda to remove surface impurities, washed, dried, and screened. For abrasive wheels, it is mixed with a porcelain bond, and fired in a pottery kiln.

In the manufacture of artificial corundum (aluminum oxide) a typical furnace mixture is: Calcined bauxite ore, 1750 pounds; coke, 100 pounds; iron borings, 350 pounds. A layer of the mixture 1 foot thick is placed on the carbon hearth, a train of graphite powder is laid from electrode to electrode, and the furnace is started. As soon as a molten path is formed, it carries the current, and more charge is added. The usual voltage is 100; from 4 to 5 tons of corundum are produced in a furnace with the expenditure of 18,000 kilowatt-hours of energy. Reduction is not carried too far, for traces (1 to 2 per cent.) of the oxides of iron, silicon, and titanium increase the toughness of the product. The iron oxide and silica present in the charge are reduced to metal, alloy, and sink to the bottom of the furnace. The iron borings in the charge are used to keep the silicon content of this alloy below 15 per cent., and thereby facilitate its magnetic separation from the crushed carborundum.

J. S. H.

Steel in Tension, Compression and Shear. F. B. SEELY and W. J. PUTMAN. (*Bulletin No. 115 Engineering Experiment Station of the University of Illinois.*)—The severe uses to which carbon and alloy steels are put in some phases of engineering, as for example, in automobile and in aeroplane construction, have developed a need for more detailed knowledge of the action of steel, under various types of stress, as well as of the factors which affect the physical properties of the material.

Our knowledge of the breakdown of elastic action of ductile materials, particularly in the case of combined loading, is limited. The various theories of combined stress lead to results which differ rather widely when applied to various machine parts or to structural elements, such as thick cylinders, flat plates, crank shafts, webs of girders, etc. The maximum shear theory of combined stress for ductile materials as expressed by Guest's law, which has gained rather wide acceptance in recent years, assumes that the elastic shearing strength is one-half of the elastic tensile strength. Available experimental results, however, have, in general, failed to justify this assumption. The importance of the limitation imposed by the shearing stress upon the elastic strength of ductile material is, of course, generally recognized. It is of special importance to know the relation between the shearing and the tensile (and compressive) elastic strengths for various grades of ductile and semi-ductile steels. The

main object of the investigation herein recorded was to determine carefully the elastic shearing strength of ductile and semi-ductile steel and to find the ratio of the elastic shearing strength to the elastic tensile strength with the hope that definite information would thereby be obtained on the breakdown of the elastic action of various grades of steel and on the limits of the theories of combined stress.

Apart from the problem of combined stress there has been also a lack of knowledge of the correct elastic shearing strength of various grades of steel and of the general nature of elastic shearing failure as well as of methods of determining the correct shearing strength from tests.

This bulletin presents the results of experiments with six grades of steel, three carbon steels and three alloy steels; namely, soft, mild, and medium carbon steel; and vanadium, nickel, and chromic-nickel alloy steel. The elastic strength in tension, in compression, and in shear is given for each of the six grades of steel.

R.

Turbine Steels. W. H. HATFIELD and H. M. DUNCAN. (*North-East Coast Institution of Engineers and Shipbuilders,* March 19, 1920.)—This Paper constitutes a report of:

1. An investigation into the response which commercial forgings made to the different forms of mechanical testing now in vogue.

2. Similar investigations into the mechanical properties of turbine parts which had given satisfactory service and also of those which had failed, with a view to eliciting reliable information concerning the relative importance of the different values to be obtained from the different forms of mechanical tests.

3. Experiments with the four steels covered in the British Electrical and Allied Manufacturers' Association specification with a view to determining the mechanical properties, under laboratory conditions, of size, heat-treatment, etc.

4. Considerations in the light of the results obtained from items 1, 2 and 3, as to which, if any, additional forms of test might be adopted for inclusion in the British Electrical and Allied Manufacturers' Association specification.

The following mechanical tests, which are briefly described in the Paper, were employed during the investigations, and the results obtained are reported: tensile, torsion, bend, Charpy, Fremont and Izod tests; Arnold alternating test; Stanton, Sankey and Brinell tests; "Shore Scleroscope" hardness tests.

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MULTIPLEX TELEPHONY AND TELEGRAPHY OVER OPEN-CIRCUIT BARE WIRES LAID IN THE EARTH OR SEA.*

BY

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Chief Signal Officer, United States Army. Member of the Institute

INTRODUCTION.

THE "key problem" in the procurement of essential Signal Corps supplies in the United States during the World War, curiously enough, turned out to be the production of the necessary braiding machines for finishing insulated wire. The bare wire itself could be obtained, the rubber insulation could be obtained, even the cotton thread with which the braiding was made could be obtained, but the necessary machinery for braiding the thread, which finally led us into the difficulties of the procurement of steel, was never anything like adequate for the enormous demands required in the field.

The braiding capacity of the entire United States, as of September 1, 1918, was sufficient for about 8000 miles of twisted pair insulated wire a month, while the requirements for the American forces alone at that date were about 40,000 miles a month. On October 1, 1918, the Allied Council reached the

* Communicated by the author. An abstract of this paper was presented to the National Academy of Sciences, Washington, D. C. April 27, 1920.

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decision that beginning March 1, 1919, it would be necessary for the United States to furnish all of this type of wire used by the Allied armies in the field, and the estimated minimum requirements for this purpose were 100,000 miles a month. To supply this amount of insulated wire would have required cargo space for overseas shipment in the amount of 14,000 ship tons a month, but had it been possible to use single conductor bare wire in place of the twisted pair insulated wire, the space required would have been reduced to 2500 ship tons a month, thus releasing the balance for transportation of food, and other vitally necessary supplies.

It is, therefore, of paramount importance to diagnose, as far as possible, the technical problems of equipment in the light of past experience and of the present trend of development.

The above facts show the necessity of developing, if possible, new methods by which a reduction may be effected in the enormous quantities of expensive and bulky insulated wire, which was so difficult to procure during the World War.

The following reasoning led to the carrying out of the experiments to be described.

1. Since we can already communicate by radio means between one submarine and another submarine, both completely submerged, it was considered that connecting two such stations by a submerged copper wire could have no other effect than to facilitate the propagation of the electromagnetic waves between the stations.

2. It was considered possible that earth or water under the action of high frequency electromagnetic forces might exhibit greatly different properties from those with which we are familiar at direct or low frequency currents.

3. It was believed that whatever high frequency energy losses might occur in the transmission over bare wires laid in earth or water, the over-all efficiency would be higher than in the case of radio space transmission where the plant efficiency is so very low.

4. It was noted by the writer in September, 1910, and discussed by him in April, 1912,[1] that the three electrode audion could be used as a potentially operated device on open circuits. This arrangement was considered suitable for the reception of the signals over bare wires in earth or water.

[1] JOURNAL OF THE FRANKLIN INSTITUTE, April, 1912, "Some Experiments in 'Wired Wireless' Telegraphy for Field Lines of Information for Military Purposes," by Major George O. Squier, Signal Corps, U. S. Army.

PRELIMINARY EXPERIMENTS.

The first experiment was an extremely simple one, as follows: A bare No. 18 phosphor bronze wire, such as is used for Signal Corps field antennæ, was laid across the Washington channel of the Potomac River from the War College to the opposite shore in Potomac Park. It was paid out from a small boat with sufficient slack to lay on the bottom of the river. Care was taken to make this preliminary experiment as simple as possible, and precaution was taken to insure that the wire itself should be bright and clean and entirely free from any grease or other insulating material. A standard Signal Corps radio telephone and telegraph set, SCR 67, was directly connected to each end of the wire, one set serving as a transmitter and the other as a receiver. At the receiving end of the line the bare wire was directly connected to the grid terminal of an electron tube in the receiving set and the usual ground connection left open. A frequency of about 600,000 cycles a second was used and the line tuned at each end by the usual methods. Excellent telegraphy and telephony were obtained.

This experiment demonstrated the possibility of transmitting electromagnetic waves along bare wires submerged in water, and the use of an electron tube as a potentially operated device on open wire for the reception of signals.

The success of this simple experiment led immediately to a more thorough consideration of the entire subject.

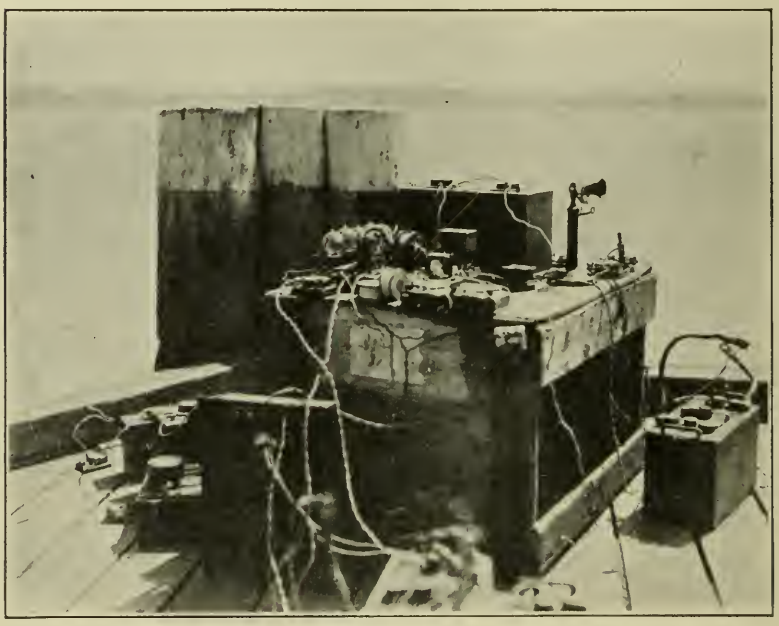
One of the questions to be investigated was the general effectiveness of the electron tube when used as a potentially operated instrument connected to an open line.

The following experiment was made in the office of the Chief Signal Officer, Washington, D. C. A strip of wire netting was buried in the snow outside, with a wire attached to it leading to the second story of the office. The upper end of this wire was connected directly to the grid of an electron tube. The reason for connecting the grid to the upper end of the antenna is, of course, obvious. For maximum sensitiveness it is necessary to connect it to the point of maximum potential of the antenna, which in the case of a linear oscillator occurs at the open end. By this arrangement, messages were readily received from distant points in the United States.

THE PROPAGATION OF ELECTROMAGNETIC WAVES OVER BARE WIRES IMMERSED IN WATER.

A series of tests was arranged to check more carefully the results of the preliminary experiments and also to get more complete information on the possibilities of the method of using bare wires submerged in water for high frequency current telegraph and telephone communication. The tests were conducted between Fort Hunt, Virginia, and Fort Washington, Maryland, located on

PHOTOGRAPH A.

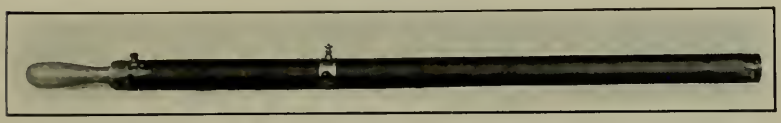


opposite banks of the Potomac River, approximately twenty-five miles south of Washington. The wire consisted of a bare seven-strand No. 18 phosphor-bronze antenna wire submerged for approximately 3000 feet (914 m.). The two terminals were brought out on the wharves where the transmitting and receiving apparatus were located, as near as possible to the surface of the water as shown in the accompanying photograph "A." The length of the exposed portion of the wire at the transmitting end was about 7 feet (2.1 m.), while at the receiving end it varied from 5 to 25 feet (1.5 m. to 7.6 m.), depending upon the location of the receiving apparatus in the various experiments.

TRANSMITTING DATA.

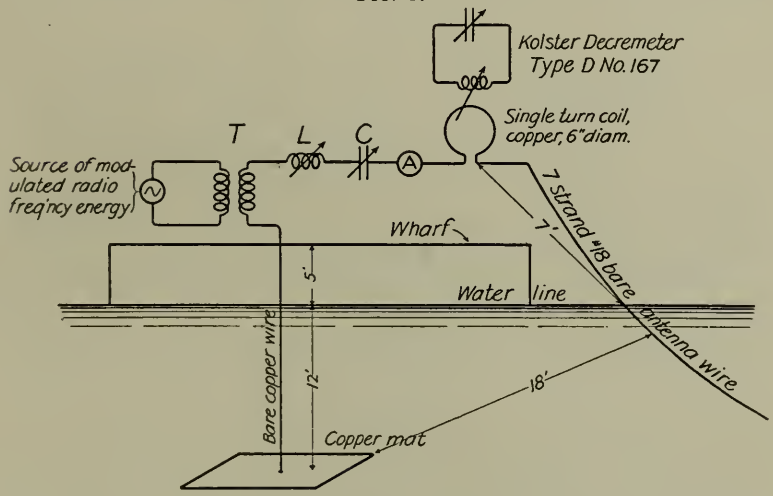
The transmitter was located on the Fort Hunt wharf on the Virginia side of the Potomac. It was of the electron tube type oscillator with Signal Corps VT-2 tubes. The particular type of circuit employed was developed especially for wired wireless transmission and possesses features which make it directly applic-

PHOTOGRAPH B.



able to this type of work. Buzzer or voice modulation was also provided for, the modulating circuit being identical with that employed in the standard Signal Corps radio telephone apparatus. The source of modulated high frequency energy was coupled to

FIG. 1.



the submerged wire as shown in Fig. 1, where the source is shown at the left, *T* is a radio frequency transformer, *L* a variable inductance, *C* a variable condenser. A transmitting wave-length of 1050 metres was adopted as this was very closely the wave-length for which the amplifier at the receiver was designed. The tuning of the submerged wire by means

of the variable inductance and capacity was remarkably sharp, a definite maximum value of current being obtained, which at resonance averaged 250 milliampères. In general, the line behaved as a lumped inductance rather than a capacity; a variable condenser in series is necessary to tune this line. At this frequency the line was found to have an equivalent inductance of about .02 of a millihenry.

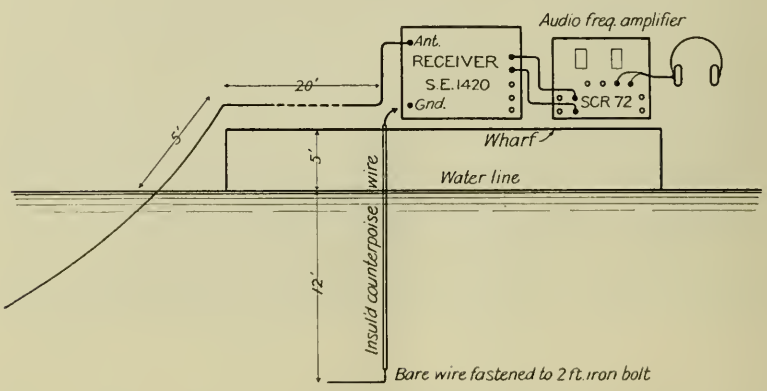
RECEIVING DATA.

The receiving apparatus was located at Fort Washington, Maryland, on the east bank of the Potomac River.

Test No. 1.

A Navy type SE-1420 radio receiver, and a Signal Corps SCR-72 audio frequency amplifier were employed. The schematic arrangement is shown in Fig. 2. The circuits of this receiver are inductively coupled, the secondary having a wave-

FIG. 2.



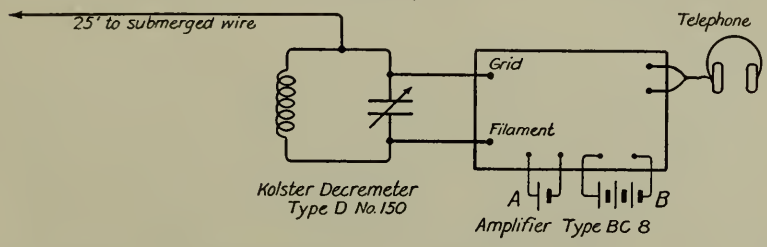
length range of 200 to 8000 metres, and may be made oscillatory or not at will. With the connections indicated in the figure, and with the ground connections either on or off, *no signals were received* in an oscillating circuit receiver when the distant transmitter was unmodulated or in a non-oscillating receiver when the transmitter was modulated by a buzzer or the voice. Both spark and continuous wave signals, however, were received from nearby radio stations when the ground connection was removed.

Test No. 2.

A simplified circuit was next used connected as shown in Fig. 3, consisting of a simple oscillatory circuit, the bare wire being connected to one terminal of the condenser and to the grid.

A Signal Corps type BC-8 amplifier, consisting of three stages radio frequency amplification, one detector tube, and two stages audio frequency amplification was used. The radio circuits of the amplifier were at resonance at 1050 metres. With this arrangement both buzzer modulated signals and speech were received from the transmitting set at the other end of the submerged wire. The tuning at the receiving end was sharp. Signals from radio stations were also received. Connecting the ground mat to the input filament terminal of the amplifier completely eliminated all signals. With the submerged wire connected direct to

FIG. 3.



the grid and the oscillating circuit removed, no signals were received.

In both of the above tests the receiving apparatus was located approximately five feet (1.5 m.) above the water level, and twenty feet (6.1 m.) horizontally from the actual terminal of the submerged wire. To determine to what extent the exposed twenty feet of horizontal wire was acting as an "antenna," the entire receiving apparatus was moved close to the terminal of the submerged wire, the exposed portion thus being reduced in length to approximately five feet (1.5 m.). Under this condition, the intensity of the received signals *was considerably reduced.* Replacing the exposed twenty feet (6.1 m.) of wire, and moving the apparatus back to its original position did not, however, bring back the signal to its original strength. Later investigation of this point showed that at this time, trouble developed in the modulating circuit at the transmitter, which accounted for the weakening of the signals, and therefore was not due to the short-

ening of the exposed wire. Disconnecting the submerged wire, with or without the twenty feet (6.1 m.) of exposed wire attached to the circuit totally eliminated all signals. This demonstrated that with the apparatus and circuits employed, the signals received were transmitted over the submerged bare wire connecting the two stations, and, that the "antenna effect" of the short length of exposed wire at the receiver was entirely negligible.

Test No. 3.

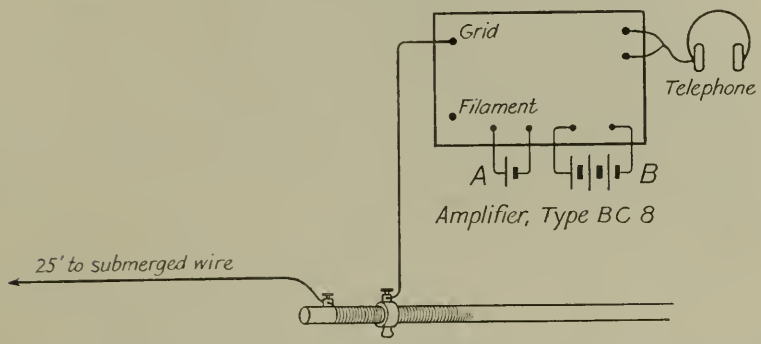
An experiment was tried in which the submerged wire was connected direct to the grid input terminal of the amplifier. It was found, however, that the latter "howled" so badly as to prevent the distinguishing of any signals. Shunting the input terminals of the amplifier with a capacity of about 200 M.M.F. eliminated the howling and brought in signals from the transmitter.

Test No. 4.

The submerged wire was led directly to one terminal of a single layer coil. The diameter of this coil was 1½ inches (3.8 cms.), wound with No. 36 double silk-covered wire, length approximately 28¼ inches (71.75 cms.), total number of turns, 4100. The other terminal was left free. A brass ring about one-half inch (1.27 cms.) wide, split longitudinally and provided with a binding post and small rubber knob, could be slid over the coil for the purpose of locating points of loop potential on the coil. This ring or band was completely insulated from the coil winding. A short flexible lead connected this band to the input grid terminal of the amplifier used in the preceding experiments. The circuit is shown diagramatically in Fig. 4. Standing waves were found to exist on the coil, and the buzzer signals were received. Two potential loop points were noted on the coil; the one giving the louder signals being that nearer the free end of the coil. The coil was turned in a horizontal plane while connected to the submerged wire, but no directional effects were observed. As in the previous experiment, to eliminate howling, it became necessary to shunt the input terminals of the amplifier with a small capacity. Radio signals from nearby land stations, and telephone conversation from a Navy airplane in flight were heard by this method.

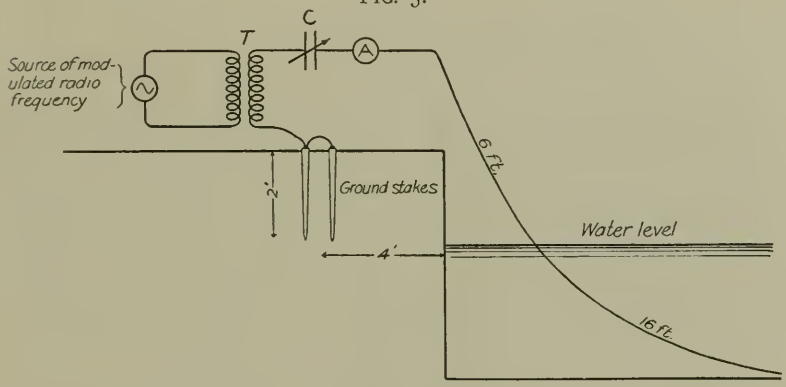
To make certain that in the above experiments the bare wire constitutes the necessary connecting link between the two stations through which the high frequency current flow takes place, and that the energy is not in some way transmitted entirely or in part

FIG. 4.



through the body or over the surface of the water, the following experiment was made. The connections are shown in Fig. 5. The line consisted of a bare copper wire approximately 22 feet (6.7 m.) in length, of which 16 feet (4.9 m.) were submerged in

FIG. 5.

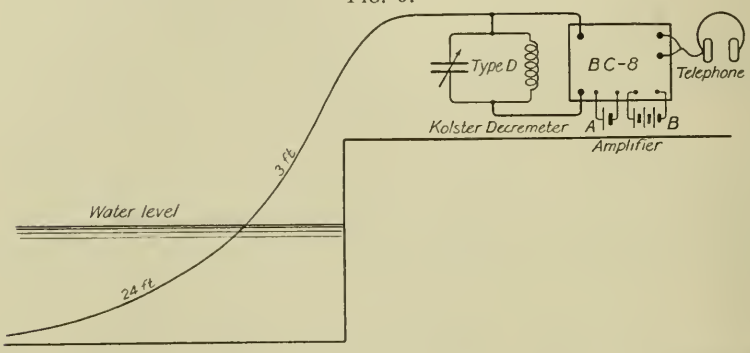


the water, the outer end of which was left free. The other terminal was connected to two metallic ground stakes buried in the earth to a distance of about 2 feet (0.61 m.). The average distance between the ground stakes and the water was about 4 feet (1.2 m.). The transmitting wave-length was 1050 metres, as in the Fort Hunt-Fort Washington tests, and maximum cur-

rent obtainable 200 milliampères. In contrast to the results obtained in the preceding tests, it was impossible to get any marked resonant effect with this short submerged wire. As the series capacity, *C*, Fig. 5, was increased, the line current slowly increased but did not, however, reach a resonant maximum value.

The receiving apparatus used was identical with that employed in the preceding test. The distance separating the two stations was approximately 2000 feet (0.6 km.). At the receiver, the line consisted of 27 feet (8.2 m.) of bare wire, of which 24 feet (7.3 m.) were immersed in the water, leaving 3 feet (0.9 m.) exposed. A type D Kolster decremeter and a type BC-8 Signal

FIG. 6.



Corps amplifier served as a receiver, the connections being as shown in Fig. 6.

With this arrangement, employing no ground connection, and with the transmitter operating as described, using buzzer modulation, no signals were received. Employing the submerged wire as a ground, and a wire of about 60 feet (18.3 m.) in length laid upon the stone sea wall as an antenna, time signals were received from the Navy Station at Arlington, Virginia, but no signals were received from the transmitter at the other side of the river. Using the connection shown in Fig. 6, it was impossible to receive signals even from the Arlington Station.

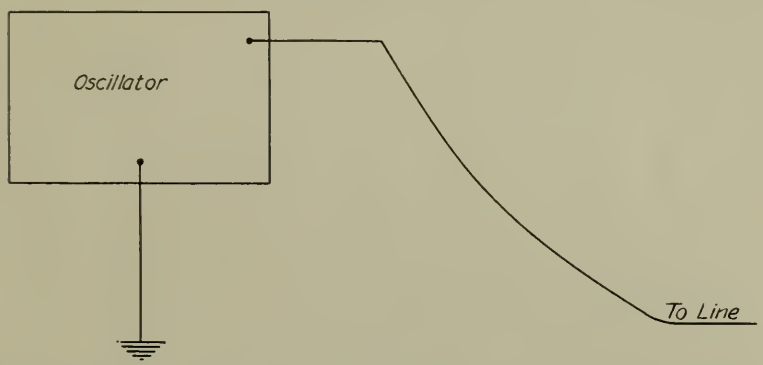
It is evident from the negative results of the above test, that the high frequency current flow must be confined more or less to the bare wire connecting the two stations. We are not prepared at this time to offer any explanation regarding the actual mechanism of the energy transfer. It may well be that the bare wire functions as a guide, the electromagnetic energy being con-

fined to a finite cylindrical layer of water surrounding the wire. But whatever the true explanation may prove to be, it was established by these experiments that high frequency currents can be transmitted on bare wires submerged in fresh water.

EXPERIMENTS WITH BARE WIRES LAID ON THE GROUND.

The Signal Corps is now required to furnish lines of intercommunication in each of the three media, *viz.*, air, earth and water, or any combination of these. As examples: (1) one airplane to another airplane, (2) one military dugout to another military dugout, and (3) one submarine to another submarine, both submerged. The earth crust consists of such widely differ-

FIG. 7.



ent character of materials, depending upon the locality, that the propagation of electromagnetic waves in this medium should in general differ with the particular character of the earth. Water, on the other hand, being a much more homogeneous medium, should exhibit more regular and orderly results, and this in general has been the experience thus far in these experiments.

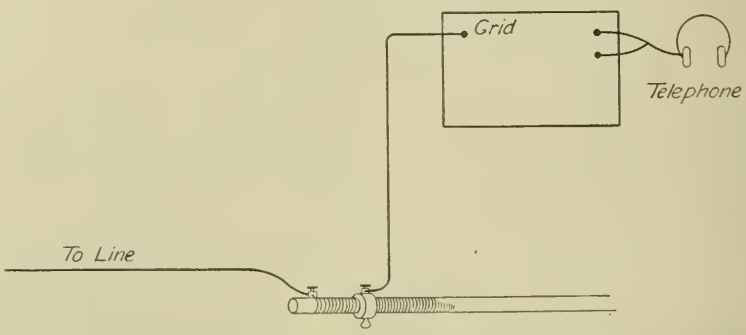
The work at the radio laboratories at Camp Alfred Vail, Little Silver, New Jersey, was confined to experiments on the propagation of electromagnetic waves over bare wires laid on the surface of the earth or completely buried in the earth, the object being a study of the effect of the earth as a surrounding medium. Many experiments were made to obtain information of the various factors which may have an influence on the final results. It would make this paper too voluminous if an atempt were made to recount here in detail all of the experiments. It will suffice,

therefore, to give only a general summary of the methods employed and the results obtained.

No attempt has been made to determine to what distance these methods may be made effective for the transmission of messages.

Tests were carried on between the main laboratory and a small field laboratory one and three-quarters miles distant (2.8 km.). A bare No. 16 wire was laid on the surface of the earth connecting these two stations. The radio telephone instruments used at each end were the standard Signal Corps SCR-67 sets, which comprise an oscillating transmitter of the electron tube type. The schematic diagrams of the transmitter and the receiver are shown in Figs. 7 and 8. The transmitting current was about 100 milliampères at any of the wave-lengths available with these sets,

FIG. 8.



which covered a range of approximately 200 to 550 metres. Good telephone communication could be maintained between these two stations with the above equipments.

Tests were also made to ascertain if any standing wave formation occurs on the line. The method used was to get the current intensity at different points on the line by opening it at different points and inserting a hot wire milliammeter. At distant points where the current was very small, the hot wire milliammeter was replaced by a low resistance thermo-couple and a single pivot Paul microammeter. It was found that the current continually decreased with the distance from the transmitting end. The line was then cut at a point three-eighths of a mile (0.6 km.) distant from the transmitting station and left open. Ammeters inserted at intervals along this section of the line at once indicated the existence of standing waves. An investigation was then made with a search

coil circuit consisting of a small loop tuned by a variable condenser and an electron tube detector and two-stage amplifier. By moving this coil along the line the loops and nodes of the standing waves were located. The wave-length used in these tests was 250 metres, and the transmitting current about 120 milliampères.

BARE WIRES BURIED IN THE EARTH.

Experiments were also made at Little Silver, New Jersey, connecting two stations by a bare wire buried in the earth at a depth of about eight inches (20 cm.). A furrow was plowed between the two stations and a bare No. 16 wire was then laid in this furrow; a second furrow was plowed back along the side of the first one, so that the earth from the second furrow was turned back into the first, covering the wire. The soil is moist, sandy loam, being only a few feet above tidewater. Signal Corps SCR-67 radio sets were used for transmitting and receiving purposes, one connected at each end of the buried wire. With this arrangement telephone and telegraph communication was established over a distance of about a half mile (0.8 km.). In general at the frequencies used the line behaved as an inductance.

In the case of the propagation of high frequency currents over bare wires laid on the surface of the earth or buried in the earth, the electromagnetic energy associated with it is apparently confined only to a limited region surrounding the wire. If a bare wire, open at the receiving end, whether laid on the surface of the earth or buried in the earth, were considered as a radio antenna, it would be expected that signals would be heard in a region along the prolongation of the wire in a direction opposite to the open end, in accordance with the well-known phenomena relating to directive antennæ. As a matter of fact, however, the experiments showed just the reverse. Signals were always located in close proximity to the wire itself, and followed it about through angles or in straight lines as the wire was laid.

Another remarkable effect observed in connection with the experiments on the propagation of high frequency currents over buried wires was the influence of a comparatively thin layer of soil in screening the electromagnetic effects due to the current flow in the wire. The following experiment was made: Signals were transmitted over the bare buried wire, and an exploring

coil, with a suitable detecting instrument, was moved along the buried wire at a fixed distance from it. It was found that by uncovered a short length, say 5 feet (1.5 m.), of the wire immediately beneath the coil the signals would appear, and would disappear again when the earth was put back over the wire. From a military standpoint this screening effect of comparatively thin layers of certain kinds of soil is evidently very important. It serves to separate and isolate certain radio phenomena on bare wires in earth to secure secrecy which is so necessary for military purposes, and so difficult and well-nigh impossible to obtain in the air.

MULTIPLEXING.

No special mention has been made of the multiplex features in connection with these open circuit lines, whether buried in earth or water. It is self-evident that the general principles of multiplexing over wires in air by using radio frequency carriers are also applicable to wires in earth or water.

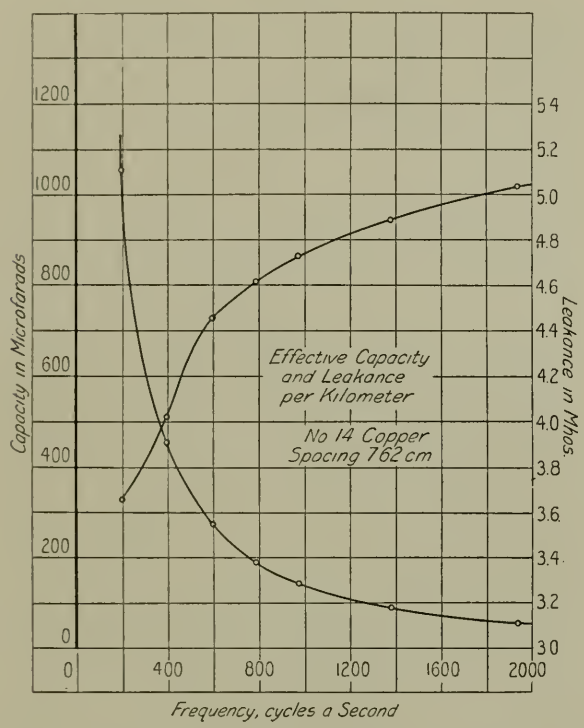
BUREAU OF STANDARDS EXPERIMENTS.

A detailed laboratory study of the phenomena connected with the propagation of high frequency currents on bare wires submerged in fresh water is also being conducted in the Signal Corps research laboratory at the Bureau of Standards. The object of these researches is to determine the electrical constants of bare wire submerged in water when subjected to high frequency currents. A suitable tank for this purpose was available at the Bureau, the dimensions of which are as follows: 125 metres long, 2 metres deep and 2 metres wide. Two wires were placed in the tank, serving as a to-and-fro conductor, and constituting a complete transmission line immersed in water. An electron tube oscillator was used as a transmitter and measurements were made to determine the apparent impedance of the system with the remote end short-circuited and also open-circuited. From these measurements the electrical constants of the line were calculated. The research has not been completed yet, but the information obtained in regard to the capacity and leakance may be of considerable interest, and are accordingly given here in the accompanying curves, Figs. 9 and 10. It is seen that at low frequencies the capacity is extremely large, about 1200 microfarads per kilometre, the equivalent of an entire Atlantic cable, but dimin-

ishes very rapidly as the frequency is increased, and at a frequency of about 40,000 cycles a second, the capacity practically vanishes. The leakance increases with the frequency up to about 5000, and then begins to slowly decrease as the frequency is increased. Experiments are now being conducted at still higher frequencies.

The results were surprising, particularly the high capacity

FIG. 9.



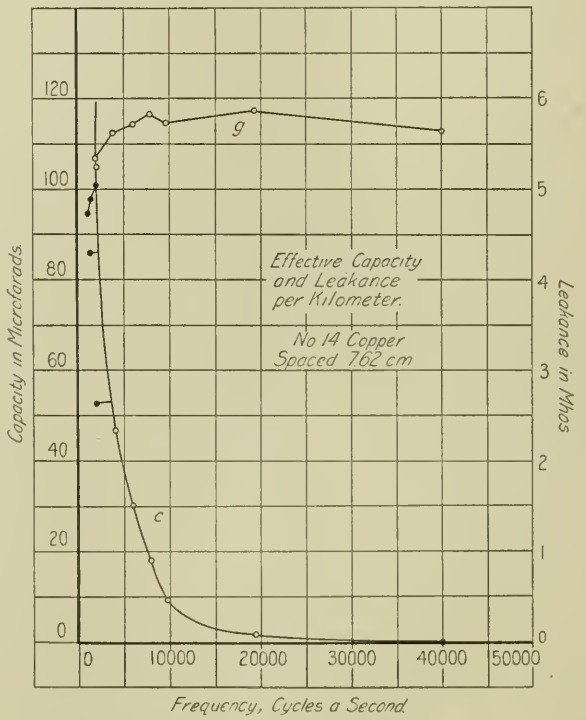
values at the low frequencies. The experiments apparently show that the frequency of the current used has a marked influence on the behavior of water as a medium, and is entirely different from what it would be for direct or low frequency currents.

It must be noted, however, that in the calculation of the values given, the usual transmission formulæ were employed, which may not be applicable in this case. It is expected, however, that further experiments will be made under resonance conditions, and at still higher frequencies.

RESONANCE WAVE COILS.

In the investigation of the problems discussed in the preceding sections, open circuits were used and the electron tube employed as a potentially operated device, the grid being directly connected to the line. To get the best results, it was necessary to devise a method for securing high potential points at the receiving end of the line without losing the advantage of tuning. This

FIG. 10.



was accomplished by the use of a resonance wave coil connected to the line, and adjustment obtained by either moving along the coil the end of the wire connected to the grid, or sliding along the coil, a narrow metal ring connected to the grid, this constituting a capacity coupling between the grid terminal and the coil. Coils of various dimensions were made up of wave-length ranges from 250 metres to 1800 metres. A separate study of the electrical characteristics of these coils as a means for receiving radio signals is being conducted in the Signal Corps laboratories.

For the present purpose it will suffice to give here only a general statement in regard to the characteristics of the resonance wave coil receivers and the results obtained. The coils were made up in the form of long helices uniformly wound with very fine wire so as to give uniformly distributed inductance, capacity and resistance, except for the disturbing end effect. The inductance per unit length is high and, therefore, in a comparatively short coil, the equivalent condition of a long line is obtained in the matter of wave development. As an illustration we may give the data for one coil as follows: Diameter, 11.5 cm.; length, 58 cm.; number of turns per cm., 34; total inductance of coil calculated, 80.5 millihenrys; fundamental wave-length measured, 1700 metres. Such a coil connected to an antenna or bare wire in water or earth, as in these experiments, can be used for tuning and at the same time advantage can be taken of the wave development on the coil, and the highest potential point used for obtaining the greatest sensitiveness in the receiving of the signals. This is practically the way in which the wave coils were used in the experiments described above.

Aside, however, from its use as a tuning element in connection with antennæ or lines, it was found in the course of the experiments that a resonance wave coil can also function as the antenna, so that by itself it constitutes a complete antenna system. The coil may be grounded at one end or it may be entirely free. In either form it can be utilized as a means for receiving radio signals.

It may be noted that in an antenna of this kind all the electrical constants, inductance, capacity, resistance and the e.m.f. induced in it by the incoming signal are of a distributed character, which makes it in a sense an ideal wave conductor.

No complete data is yet available in regard to sensitiveness and selectivity of the wave coil antenna as contrasted with the usual forms of closed circuits now used. Very promising results, however, are being obtained in the Signal Corps laboratories and the study of the electrical characteristics of the wave coil is being continued.

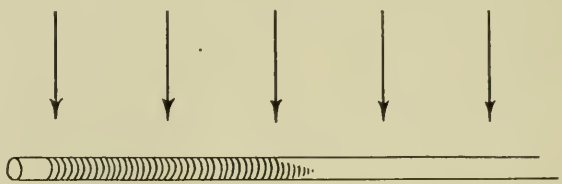
DIRECTION FINDING.

The experiments with the resonance wave coils led to the discovery that it possesses remarkable directive properties. A change in the position of the coil with respect to the transmitting

source changes the voltage and current distribution on the coil and accordingly produces a shift in the position of the point of maximum potential. The shift occurs in one direction or the other, depending on the position of the transmitting source with respect to the coil. Hence, this offers a means of determining not only the plane in which the electromagnetic waves travel, as is the case of the usual loop antenna, but it determines the actual direction from which the signals proceed. The explanation appears to be as follows:

If the electromagnetic wave front is parallel to the axis of the coil, as indicated diagrammatically in Fig. 11, each element of the coil has induced in it an e.m.f. of the same intensity and the same phase. We have a condition of a conductor of uniformly distributed electrical constants, and acted upon by uniformly distributed e.m.f., from which results a definite potential and current wave distribution on the coil, the exact form depending on the length of the coil, frequency, and terminal conditions. By moving the terminal of the grid of an electron tube along the coil,

FIG. 11.

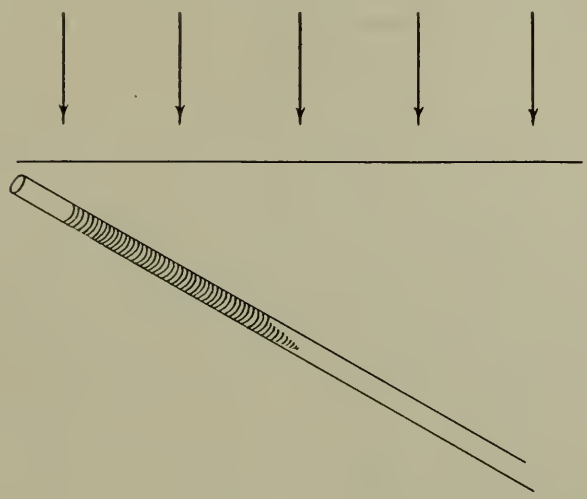


the point of maximum potential is readily determined. The connection between the grid and the coil need not be an actual physical contact. In most experiments a capacity connection was used, consisting of a narrow metal ring sliding freely on the coil. If now the coil is turned at some angle, as shown in Fig. 12, the e.m.f. induced in the coil is no longer uniformly distributed, since there is a difference of phase between the e.m.f. acting on each element of the coil arising from the difference in time required for the electromagnetic wave to reach the different parts of the coil. As a result, the voltage and current distribution on the coil is altered and the point of the maximum potential loop is accordingly shifted in one direction or another, depending on the direction of inclination of the coil to the direction of propagation of the signal. It was also found that when the longitudinal axis of the coil is perpendicular to the direction of propagation of the sig-

nals two potential loops may occur, one near each end of the coil, these potential loops being substantially of the same amplitude. When the coil is turned through an angle in the horizontal plane the potential loop near that end of the coil which points in the general direction towards the transmitting source is of a greater amplitude than that of the loop near the end of the coil pointing away from the station. This, therefore, offers a suitable means for determining the actual direction from which the signals proceed.

The above is only a brief statement of the general principles

FIG. 12.



governing the operation of resonance wave coils as applied to direction finding.

SUMMARY.

For military reasons, if for no other, as stated in the introduction of this paper, the Signal Corps has recently undertaken certain investigations in the phenomena connected with the transmission of high frequency electromagnetic waves over bare wires in earth and in water.

In attacking the problem from various angles and in carrying out these investigations the research staff of the Signal Corps laboratory at Camp Alfred Vail, Little Silver, New Jersey, was directed to carry out experiments on bare wires laid on the surface of moist ground and also buried in earth. The staff at the

Signal Corps research laboratory at the Bureau of Standards was directed to investigate fundamentally the transmission of electromagnetic waves over bare wires in fresh water. In addition to this, the engineering staff of the office of the Chief Signal Officer has carried out from time to time certain experiments of a more or less crucial character which have come up for solution in the prosecution of this work at the other laboratories.

Certain data from each of these groups of engineers have been presented above. The phenomena associated with the transmission of high frequency waves over bare wires in earth or water are obscure and complex, and the writer has formulated no definite theory at the present time.

RESULTS OBTAINED.

1. Telephone and telegraph communication has been established between Fort Washington, Maryland, and Fort Hunt, Virginia, across the Potomac River, below the City of Washington, over a distance of about three-quarters of a mile (1.20 km.), by the use of a bare No. 12 phosphor-bronze wire laid in the water to connect the stations. The transmitter consisted of an electron tube oscillator which delivered a current of about 270 milliampères to the line at a frequency of about 300,000 cycles a second. At the receiving end of the line an electron tube and a six-stage amplifier were used without any ground connection. With this arrangement good tuning was obtained at both ends of the line, and telegraphic and telephonic transmission secured over the bare wires immersed in fresh water.

2. A resonance wave coil has been developed. The coil is in the form of a long helix wound with a large number of turns on which stationary waves are produced by the incoming radio signals. An electron tube is used as the detector, the grid being connected to the point of maximum potential on the coil. The wave coil may be used either as a part of the usual antenna system or a part of a line wire, or it may act itself as the antenna for picking up the energy of the signals. In the latter case the coil may be either free at both ends or grounded at one end. Good results have been obtained in either case. It has been also found that the open coil has directional properties and can be used as a goniometer. This form of radio goniometer has the great advantage that it permits not only of determining the plane where

the signals are strongest but also the direction from which such signals proceed.

3. Telegraph and telephone communication has been also established between two stations at the Signal Corps research laboratories at Camp Alfred Vail, Little Silver, New Jersey, using a bare No. 16 copper wire buried in the earth to a depth of about eight inches (20 cm.) to connect the stations. The distance between the two stations was three-quarters of a mile (1.20 km.). Frequencies as high as one million cycles a second were used. Similar communication has been carried on over a bare wire one and three-quarters miles (2.8 km.) long laid on the surface of moist earth. The current at the transmitting station in these installations was about 100 milliampères. It has been shown that a bare wire buried in moist earth with the distant end open can be tuned both at the transmitting end and at the receiving end.

SUGGESTIONS.

1. In the older art of ocean telegraphy, the elaborateness of line construction has already reached a practical limit. The best Atlantic cable of the present day is limited in operation to electric waves of frequency of the order of 10 cycles a second. The electrical construction is such as to limit the voltage employed on any long cable to from 50 to 80. The relative values of the line constants in any present ocean cable preclude the possibility of ocean telephony.

The most promising hope of improving the line construction for ocean cables is believed to be to abandon the present method of design and construction and to start with the simple case of bare wires in water using high frequency currents and study the necessary changes to produce optimum transmission.

The use of a high frequency "carrier" has the inherent advantage that the distortion phenomena accompanying present methods of long-distance transmission are eliminated, and we are principally concerned with the problem of reducing attenuation. The most suitable voltage may be employed and present multiplex methods may be utilized. The electron tube is available for both the generation and the reception of the waves.

2. During the last few years an intensive study has been made of the surface conditions of wires necessary to produce the emission of electrons, and to this intensive study, both by uni-

versities and industrial research laboratories, is due the high state of efficiency of the present electron tube. Nothing short of a similar study of the surface conditions of wires to prevent the emission of electrons instead of producing them, will finally give us the wire conductor of the future.

3. The development of types of resonance wave coils, both open at one end and at both ends, for general radio work offers an interesting field for investigation. This involves the study of the electron tube as a potentially operated device. The application of such coils properly designed for specific purposes may lead to the practical solution of a number of radio problems such as directional effects, and wave coils antennæ of very small dimensions.

4. The account of the experiments thus far conducted and the reasons which have led to the undertaking of these experiments on the part of the Signal Corps, are presented to the National Academy of Sciences at this time in conformity with the new spirit of organization for national and international research so admirably typified by the National Research Council which is under the general direction of this official body.

OFFICE OF THE CHIEF SIGNAL OFFICER,
WAR DEPARTMENT,
WASHINGTON, D. C.,
April 27, 1920.

The Spectral Distribution of the Radiant Energy of Metals. G. R. GREENSLADE. (*Physical Review*, February, 1920.)—A thin sheet of the metal was bent into a V. Working temperatures were got by directing an optical pyrometer into the V, while the outer surface of the strip radiated to the receiving device, a reflecting spectrometer and bolometer. Very instructive curves are given for iron, tungsten, and molybdenum in which wave-length is plotted against intensity of radiation for eight or more temperatures. The purity of the metal was discovered to affect greatly both the form of this curve and also the total energy radiated. "One specimen of commercial nickel at 1353° K. had a total emission of 2.5 times that of electrolytic cobalt-free nickel at the same temperature, and the energy for the wave-length of maximum emission was 3.0 times as great. This large difference was probably due to contamination of the surface by the ash contained in the impure specimen."

G. F. S.

U. S. NAVAL AIRCRAFT.*

BY

JEROME C. HUNSAKER, Eng.D.

Commander, Construction Corps, U. S. Navy, Navy Department, Washington, D. C.

In the few years that Naval Aircraft have been part of the Navy they have become so specialized by adaptation to meet specific naval requirements that they constitute to-day distinctive types of design. Before considering these peculiarly naval types, let us examine the naval functions which have governed their development.

The Navy consists of two major parts: the Fleet, which is designed to operate on the high seas in any part of the world, and the Shore Establishment, organized as Naval Districts on the coasts of the United States and the outlying possessions. The primary function of the Fleet is to discover, engage and destroy the enemy fleet. The functions of the Shore Establishment are both industrial and military. The industrial function does not concern us here. The military function is the elimination from coastal waters of the activities of enemy naval forces, in particular, raiders, submarines and mine-layers.

The Navy employs every weapon or device which is considered to be useful in connection with its mission. As the mechanical arts advance, the latest applications are introduced. Progress in any of the arts or sciences is eagerly seized upon to discover means for making use of the new knowledge in the Navy. So with aeronautics; as the art has progressed, aircraft have been developed for use in the Navy. The principles governing the design of such Naval Aircraft are the very fundamentals of the art, but the aircraft themselves represent the application of these principles to meet the needs of the Navy; that is, to fulfill functions allied to the functions of the Fleet and the Shore Establishment.

Consider the Fleet first. The Fleet must have scouts to discover the enemy and give intelligence of his strength and

* Presented at the joint meeting of the Institute and the Aero Club of Pennsylvania held Wednesday, January 21, 1920.

probable intentions. Aircraft may obviously be used for this purpose in conjunction with scout cruisers, destroyers, or battle cruisers. The range of visibility from aircraft is relatively enormous, as an observer in an airplane can go three times as fast and see three times as far as an observer on a ship. With this inherent advantage, it only remains to develop practical scouting or reconnaissance aircraft for such work. This development results from no idle arm-chair speculation, however, as the problem is limited by the restriction that the Fleet is normally at sea and the weather normally bad.

Scouting, or reconnaissance for the Fleet, may be of two kinds: First, reconnaissance at a great distance, requiring great endurance in the air; and second, reconnaissance at a short distance immediately in advance of the Fleet. For this second function, great endurance is not needed as a frequent return to the parent ship is possible. We thus will have at least two types, one characterized by extreme endurance, the other by simplicity and handiness for use from shipboard.

Another distinct type must be employed for fighting enemy aircraft which, in any future naval engagement, will surely be present. This problem presents considerable difficulty as it presupposes a battle in the sky for control of the air in advance of the actual engagement of the ships. Control of the air over a wide area can only be maintained by large numbers of airplanes of the greatest fighting capacity and the launching of a swarm of airplanes at the desired moment from the restricted spaces aboard ship seems impracticable. Consequently, special ships in the Fleet with flush decks and enormous hold spaces are necessary to act as carriers.

Before the introduction of aircraft into the Fleet, the control of gunfire was directed by a "spotter" stationed on the mast. This is the highest point on the ship from which to observe the splash of the shells, but compared with a position several thousand feet in the air, it is very low—too low, for example, to see over a smoke screen made by enemy destroyers, and too low to estimate at extreme ranges the distance from the target to the splash. The individual battleships of the Fleet have need, therefore, for aircraft to carry the fire control officer or spotter aloft.

The aircraft so far discussed are primarily concerned with air fighting and observation. There remains the offensive func-

tion which is the primary objective—to destroy the enemy fleet. Aircraft can now carry bombs powerful enough to damage a battleship or a regulation torpedo sufficient to sink her. Torpedo attack from the air cannot be stopped by the usually effective screen of destroyers and light cruisers. In fog or at night the great speed of torpedo-carrying airplanes adds so much to the element of surprise that the chances greatly favor the attack. Further-

Fig. 1.

Ship's fighting plane flying off turret platform. (U. S. Navy.)

more, booms, nets and chains across a harbor mouth will no longer render the anchorage immune from attack. The torpedo plane during the War was not developed to full effectiveness by either side, but in any future war we may expect it to play an important part.

To recapitulate, there are five essentially distinct functions for aircraft with the Fleet:

1. Long-range scouting.
2. Short-range scouting.

3. Fighting in the air.
4. Spotting or control of gunfire.
5. Bomb and torpedo attack.

The Shore Establishment divided into Naval Districts has, likewise, uses for aircraft in connection with the control of coastal waters. The first and most important is searching for

FIG. 2.

Ship's fighting plane after a water "landing." Note inflated air bags. (U. S. Navy.)

hostile raiders, submarines, mine-layers, etc., which duty may be termed "Coast Patrol."

In connection with coast patrol it may become necessary to convoy shipping into and out of ports and through dangerous waters. For this purpose aircraft are essential, not alone of course, but coöperating with an escorting force of destroyers.

In addition to the applications of aircraft mentioned so far, we have very necessary aircraft work required in connection with Advanced Base and Expeditionary Forces. Such Expeditionary Forces may usually be supposed to operate without opposition

from a highly developed air force, but such a favorable condition cannot be guaranteed. The Marines, therefore, have to be provided with the latest thing in military airplanes. Such types are similar in function and hence in design to those used by an

Fig. 3.

H. M. S. *Argus*, airplane carrier. (British Navy.)

army, and I shall not take time to discuss them as Naval Aircraft.

In the foregoing, I have briefly classified aircraft functions as based on the functions of the Navy. In considering how aircraft can fulfill these functions we are immediately confronted

with the necessity for deciding whether we require "heavier-than-air" or "lighter-than-air" types.

Under "heavier-than-air" we include all airplanes and seaplanes which are supported by their own wings. By "lighter-than-air" we designate balloons and airships or dirigibles. Kites and parachutes are not classified as aircraft.

Among "heavier-than-air" craft, we have: First, airplanes with wheels of the ordinary type; second, seaplanes with floats or pontoons to fit them to start from and alight on the water; and

FIG. 4.

Ship's spotting plane. (U. S. Navy.)

third, flying boats, being a true boat fitted with wings. These types may be somewhat mixed in special designs as, for example, a seaplane provided with wheels as well as floats to make it amphibious, or an airplane fitted with hydro-vanes and air-bags to permit emergency alighting on the water.

"Lighter-than-air" craft consist of the ordinary free balloons, or "sphericals," kite balloons of elongated form which are towed by a cable, non-rigid airships (or dirigibles) obtaining lift from a gas-bag under pressure, and rigid airships such as the Zeppelin with a rigid hull structure fitted with a multiplicity of gas-bags.

In the present state of the art we may choose one type or the other for a certain naval function, depending on clearly evident practical considerations, but for others, it is not clear whether we should favor an airship or a large seaplane. The final decision can only be made after experience with each, but by that time progress in the art may require a reversal of the conclusions reached. It is wise, therefore, to provide both and allow the stimulation of competition to develop the possibilities of each.

Let us now look at the types of aircraft already in use, and

Fig. 5.

Ship's spotting plane. Same machine as Fig. 4, fitted with floats. (U. S. Navy.)

consider what is the state of the art, the requirements of the service, and the possibilities for meeting them in the immediate future.

For long-distance scouting at sea, it is primarily a question of the greatest endurance and radius of action. There is no aircraft which approaches the rigid airship in these characteristics. The present-day German and British rigids of 2,000,000 cubic feet volume have a maximum radius of action of over 3000 miles and can stay out about five days. The best that has been done to date with a flying boat is about 1500 miles. While the radius seems to be half that of the airship, the comparison is less favorable when it is considered that the flying boat cannot keep in the air quite a day. On the other hand, the airship can

drift about while waiting or observing without consumption of fuel; the crew are comfortable and probably will do better work; radio is more powerful and communication with the Fleet more certain.

The rigid airship, according to Admiral Jellicoe, is worth two light cruisers for scouting in favorable weather. The last words must be pondered, for "favorable weather" is a relative

FIG. 6.

Torpedo plane at instant of launching torpedo. (British Navy.)

term. Fog is no doubt most unfavorable weather for a seaman, but for an airship at sea low fog may give it a distinct advantage in scouting. The airship will, however, have to cope with storms and heavy rain and snow. Due to her great endurance and the usually local character of really violent meteorological disturbances, the airship can be expected to avoid getting into trouble. Naturally, we must assume adequate weather reports by radio from the ships coöperating with her. However, the necessity to avoid storm centres will put a stop to any scouting for the time being. A flying boat is relatively unaffected by storms while

in the air, but she cannot alight on the water under such conditions. With present power plants such a possibility must always be kept in view.

The latest German rigid airships have a maximum speed of about 70 land miles per hour and the NC-4 flying boat has a top speed of about 90 miles per hour. To cope with gales of general extent the airship is clearly at a disadvantage. It is

Fig. 7.

Coast patrol and convoy type. Flying boat F-5 at start. (U. S. Navy.)

probable that, following the present trend of design, the airship speed will not be pushed much, if any, above 80 miles, while a speed of 115 miles for the flying boat is already in view. It seems evident that the relative utility of the airship and flying boat depends upon weather conditions. For scouting over the North Atlantic in seasons of high winds, the flying boat may be the more suitable.

I have not here considered large land type airplanes which, while comparable with large flying boats in speed and endurance

in the air, are unfit to send out to sea, as they cannot land to refuel or make repairs, but must make non-stop flights from land to land. The scouting requirements of the Fleet are unlikely to be always in waters conveniently near the aerodrome. The flying boat will have to be based on shore for hauling out and overhaul, but normally she will follow the fleet, being supplied with fuel from a supply ship, except in rough weather, when she will take refuge in

FIG. 8.

Coast patrol and convoy type. Flying boat F-5 at anchor. (U. S. Navy.)

the nearest sheltered water like any small craft. There is no need for an expensive and elaborate chain of landing fields, as all the bays and rivers of the world are "landing" spots more level than the most perfect field on shore.

The rigid airship, like the airplane, must start from and return to a land base, but her five-day endurance minimizes this restriction. There must be, however, airship bases located at all strategic points near which the Fleet is likely to operate.

The cost is interesting for comparison. The rigid airship

of the greatest size yet constructed costs about twenty times as much as the NC-4, the largest flying boat yet built. The shed to house her also costs about twenty times as much as housing on shore for NC-4. Considering cost alone, we should hope the airship were as useful as twenty flying boats. Under some conditions this may be the case. Any number of flying boats bringing in negative reports is worthless compared with continuous positive

Fig. 9.

Flying boat NC-4, long range scouting type. (U. S. Navy.)

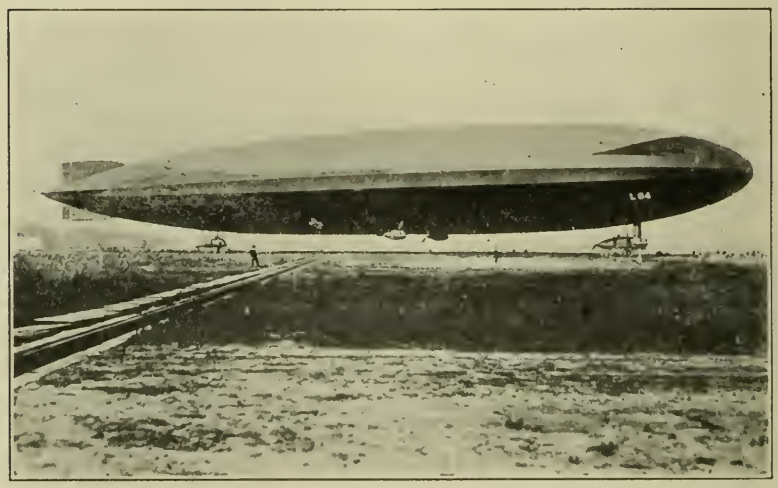
and definite information from an airship keeping the enemy under constant surveillance.

It must not be forgotten that the rigid airship of the present day is very vulnerable to attack from airplanes, as has been demonstrated over London to the entire satisfaction of the Germans. The German bombing raids over London were entirely unjustifiable, either on grounds of ordinary decency or from tactical considerations. The legitimate function of the Zeppelin was scouting over the North Sea where most valuable work was

done. Indeed, on more than one occasion, the Zeppelin scouts permitted the German High Seas Fleet to avoid action and certain defeat by the British Grand Fleet.

It is hoped that at some future day helium may become cheap enough to be used in place of hydrogen. Until that time comes, rigid airships must avoid coming within the range of enemy ships or aircraft. At sea, with its immense distances this is quite possible to accomplish. There is no need to come within range of a ship's guns in order to observe its movements and, in general, airplanes can be avoided by rising into the clouds.

FIG. 10.



Zeppelin L-64. (German Navy.)

The airship, at high altitudes, can rise faster than an airplane as the latter climbs by engine power, which is becoming weak, while the former climbs by dumping ballast, which is always effective. Furthermore, at high altitudes, the airship suffers no loss in speed while the airplane, no matter how fast at sea level, loses speed rapidly with altitude. During the chase of an airship, it is also to be remembered that the airplane may come under the fire of several guns of the airship. On the whole, the airship should be able to keep clear of hostile aircraft.

The present state of the art indicates the rigid airship and the large flying boat as rivals as scouts for the Fleet. The rigid

airship in its latest development is represented by the Zeppelin and the flying boat by the NC-4 type of our own Navy. Is it likely that the possibilities of the immediate future indicate any important change in the relative merits of the two types?

Curiously enough, it has been proposed to build a rigid airship twice the size of the present-day Zeppelins and at the same time the flying boat adherents have proposed to double the NC-4.

Fig. 11.

Non-rigid airship C-1. (U. S. Navy.)

Such an increase in size at one step appears to be the maximum it is safe to attempt and it will probably take the next few years to see light ahead. From a preliminary analysis, however, it appears that increase in size is more favorable to the airship than to the flying boat, and as we build larger and larger airships the flying boat is left farther behind.

I shall not burden this paper with the detailed analysis, but fundamentally the difference results from the fact that for the airship the buoyancy of the hull is increased as the cube of a linear

dimension, while for flying boat wings the lift remains the same per square foot or increases as the square only. As airships are made larger the margin of the total lift available to carry fuel and stores is increasing, and an endurance of seven or eight thousand miles is not difficult to reach with an airship of about

FIG. 12.

Kite balloon. (U. S. Navy.)

4,000,000 cubic feet. In other words, by doubling the size of the airship the endurance may be doubled.

On the other hand, the flying boat, if doubled in size, will be likely to add but 25 or 50 per cent. to its endurance. The large flying boat has a decreasing margin of lift available for fuel and stores and an increase in size is uneconomical unless the greater size permits use of better structural arrangements, or better structural material to such an extent as to overcome the unfavorable factors which are inherent in the problem. The effort of the designer will be to provide the larger flying boat with no worse

a ratio between useful load and total weight than we have to-day on the NC-4.

The principal advantage of the large airship as compared with the large flying boat is derived from more economical propulsion. The resistance to propulsion of an airship is largely due to the hull or envelope and it is known from wind tunnel experiment and confirmed by experience that this resistance is represented by an expression of the form:

$$R = KS^{n/2} V^{n}$$

where n lies between 1.86 and 2, and near 1.9. To simplify the argument, let us take $n = 2$, on the safe side. Then $R = KSV^2$, where S is the "wetted surface" or surface exposed to air friction, V the velocity and K a coefficient depending on form. The resistance thus varies as the square of a linear dimension and the square of the speed. The necessary power of the engine is:

$$P \sim KL^2V^3$$

But the lift depends on the total volume which varies as L^3 and hence the tons of weight per horse-power vary as:

$$\frac{\text{Lift}}{\text{Power}} \sim \frac{L^3}{KL^2V^3} \sim \frac{L}{KV^3}$$

For larger ships this ratio becomes more favorable. Since the proportion of the total lift available to carry fuel is known to be more favorable in such large ships as have been built, it is on the safe side to consider such proportion constant for purposes of argument. The weight of fuel then varies as the total lift or as L^3. The endurance in hours is the quotient of fuel available and fuel consumed per hour. This quotient is proportional to the ratio given above, or to tons per horse-power:

$$\frac{L}{KV^3}$$

The larger ship will go farther at the same speed in a manner at least directly proportional to the length.

As a matter of fact, experience has shown that the larger ships actually have a greater fraction of the total lift available for fuel. Nor is the resistance so high as assumed. Therefore, the increased endurance of larger airships is even greater than would be predicted from this simple analysis.

The following table of German Zeppelins, illustrates a progressive improvement with size, but it cannot be expected that such improvement will be continued indefinitely at the same rate, for we should eventually reach a ship such that the empty weight was practically nothing. The rather abnormal improvement shown is due to the fact that the early ships were the small ones and their design was rather crude and heavy. The larger ships are late designs of great refinement. However, the improvement is significant:

Type	Date	Volume cubic feet, 100 per cent. full	Length, feet	Diameter, feet	Lift		Useful	B. H. P., total	Speed, full power, M. P. H.	Endurance	
					Gross tons	Useful tons	Gross, per cent.			Full power, miles	Half power, miles
L-1	1912	793,000	517	48.5	22.8	....	....	540	47	....	....
L-2	1913	918,000	525	54.0	26.4	7.3	27.6	800	49	1100	1750
L-3-9 inc.	1915-16	919,000	525	54.0	26.4	....	....	800	49	....	....
L-31-38 inc.	1916-17	1,945,000	643	78.7	56	26	46.5	1440	60	3200	5050
L-39, 40, 43, 45 and 47	1917-18	1,945,000	643	78.7	56	28.6	51	1440	60	3300	5200
L-44, L-46	1917	1,945,000	643	78.7	56	29.5	53	1200	62	4200	6700
L-48-52 inc.	1917-18	1,945,000	643	78.7	56	30	54	1200	62	4652	7350
L-53-64 inc.	1917-18	1,974,000	643	78.7	57	29	51	1500	68	3950	6300
L-70	1918	2,200,000	693	78.7	63.4	35.7	56	2100	80	3900	6300
L-71	1918	2,420,000	743.1	78.7	70	42	60	1800	74	4800	7600
Bodensee	1919	706,300	393.7	61.3	20.3	7.3	36	1040	80.7	1550	2500
R-38 (British)	1921	2,724,000	694.4	86	78.6	45.9	58.4	1950	70	5100	8100

The flying boat cannot be studied in exactly the same manner as the total lift is given, not by the volume of gas, but by the wings. The lift of an aeroplane wing is represented by an expression of the form:

$$\text{Lift} = KSV^2f(i)$$

where S is the area, V the velocity, K a coefficient depending on the form of the wing and $f(i)$ a function of the angle of attack, i of the wind on the lower side of the wing. It is an experimental fact, so far without adequate explanation, that an aeroplane wing is useful only between angles of 0 and 14 degrees about. Near 14 degrees, there is a change in the nature of the flow over the wing and violent turbulence is set up. For an angle greater than this critical angle the lift is no greater, and may even be less, while the resistance or drag becomes relatively enormous. Consequently, the aeroplane gets its practical maximum of lift at about 14°, and for a given weight to be carried can fly slowest at this altitude. Since the plane must get up to this speed by a

run on the ground or over the surface of the water, before she will take the air, this limiting speed is the speed of starting and must be kept within practical limits.

For airplanes of the land type the starting speed is between 45 and 55 miles per hour. If anyone has ever attempted to drive an automobile over a pasture or meadow at such speed, he will have an idea of the risk and danger of getting into the air with a large airplane.

The conditions for a seaplane are somewhat more favorable because the water is more nearly level than the average pasture. With modern boat hulls (like the NC-4) a get-away speed of over 60 miles per hour is quite permissible even in rough water. The seaplane or flying boat can, therefore, carry into the air a greater weight for a given wing area simply because the speed can be permitted to go up.

In general, however, the starting and landing speeds, of all heavier-than-air craft are restricted by practical considerations and for this reason we may assume that the minimum velocity in the expression, Lift $= KSV^2f(i)$ a maximum, remains substantially constant.

If we build larger flying boats, the ratio $\frac{\text{Lift}}{\text{Surface}}$, therefore, remains constant. The wing area must increase directly as the total weight of the machine.

The weight of larger wings carrying the same unit load of, say, 9 or 10 lbs. per sq. ft., naturally tends to increase faster than the area of such wings. The larger wings have a greater spread and are more difficult to brace and keep stiff and strong.

The carrying capacity of a wing increases with the square of a linear dimension, but the structural members of which it is composed vary, some as L^2, some as L^3, and some even as L^4. The simple geometrical expansion of a small wing to make a large one would be bad engineering.

Fortunately, one need not be discouraged by such theoretical considerations as we have learned from past experience that, by the introduction of new and better structural materials and arrangements in larger wings, the weight can be kept down nearly to direct proportionality. That is: the weight of large wings per unit area is the same as for small ones carrying the same unit load.

This result, quite at variance with the theoretical deductions of several learned writers, is illustrated by the following table:

Name of machine	W (Gross weight)	A (Wing area)	$\frac{W}{A}$	Weight of wings per square foot (including struts and wires)
R-6	3,964	613	6.4	1.32
HS-1-L	5,902	653	9.0	1.78
HS-2-L	6,373	803	7.9	1.69
H-16	10,900	1,164	9.36	1.76
Caproni	12,810	1,420	9.02	1.15
F-5-L	13,000	1,397	9.3	1.81
F-3	13,400	1,425	9.4	1.70
F-6-L	13,514	1,397	9.7	1.55
NC-2	22,600	2,441	9.3	1.59
NC-4	28,000	2,441	11.5	1.59
Tarrant	44,862	4,950	9.06	1.93

The variations in the weight of wing structure per square foot of area are no more than would be expected from the different designers of these widely differing machines. A point of interest not brought out in the table is that the structural factor of safety has fallen from 6 in the HS type to 3 in the NC type. This sacrifice is necessary in order to avoid weight. It is also justified in view of the fact that the very large machines are not called on to perform acrobatic movements in the air.

After the wings, the next principal weight group to consider is the hull. The hull of a flying boat is designed to float the machine on the water with sufficient reserve buoyancy to give stability and seaworthiness in a seaway. In addition, the hull must afford hydroplaning surface enough to permit high speed over the water at the "take-off." Experiments in the towing tank, confirmed by practical experience, show that all the requirements for a flying boat hull are met if the volume of the hull is kept directly proportional to the total weight of the machine. That is to say, the lines of a large hull may be expanded from the lines of a small one with a scale ratio equal to the cube root of the displacement. The structural weights of such hulls will be almost directly as their displacements, or as L^3, where L is any linear dimension. There is, therefore, little relative gain in hull weight in the larger boats.

An analysis of the weights of a number of large land machines indicates that the weight of fuselage and landing gear is about the same as the weight of the equivalent flying boat hull which combines the two functions.

The power plant weight depends of course on the speed required. Very fast fighting planes may have abnormally big engines which will account for an abnormally large proportion of the total weight lifted. Eliminating these, as well as abnormally slow-training machines, we have the following table from which it seems clear that the percentage power plant is independent of size:

Name of machine	W (Gross weight)	$H.P.$ (Total power)	w (Power plant weight)	$\frac{W}{H.P.}$	$\frac{w}{W}$ (per cent.)	$\frac{w}{H.P.}$
R-6	3,964	200	1,159	19.8	29.2	5.77
HS-1-L	5,902	360	1,566	16.4	26.5	4.33
HS-2-L	6,373	360	1,600	17.7	25.1	4.41
H-16	10,900	720	2,831	15.1	26.0	3.92
Caproni	12,810	1,080	4,400	11.8	34.5	4.07
F-5-L	13,000	720	2,876	18.1	22.8	3.98
F-3	13,400	700	2,939	19.1	21.9	4.2
F-6-L	13,514	720	2,893	18.8	21.4	4.01
NC-2	22,600	1,080	5,674	20.9	25.1	5.24
NC-4	28,000	1,600	7,448	17.5	26.6	4.65
Tarrant	44,862	3,000	9,217	15.0	20.6	3.07

Excepting the Caproni, which is obviously over-engined, the table shows that the power plant for general utility machines of long endurance amounts to about 25 per cent. of the total weight and the power plant itself weighs about 4 pounds per horse-power. This includes the complete power plant with all accessories, piping, and auxiliaries.

The figure for the ratio, total weight lifted per horse-power, is about 18 for long-distance flying boats, and while it may vary between 15 and 20 in different designs, such variation is independent of size. We may safely conclude from this survey of past experience (as well as from an analysis based on dimensional theory which I shall not attempt here) that the ratio $\frac{W}{P}$ is substantially constant for large flying boats.

Since the weight of the power plant increases as the gross weight of the planes, and we have seen above that the weight of boat hull and wings increase at least as rapidly, the empty weight of the complete plane should also increase as rapidly as the gross weight lifted. The difference between weight empty and gross weight is the useful load available for crew, fuel, cargo, etc. The useful load should be, therefore, a constant fraction of the gross weight. The following table bears out this statement:

Name of machine	W (Gross weight)	V (Useful load)	$\frac{V}{W}$ (Per cent.)
R-6	3,964	844	22.3
HS-1-L	5,902	1,832	31.1
HS-2-L	6,373	2,113	33.1
H-16	10,900	3,500	32.1
Caproni	12,810	5,110	39.8
F-5-L	13,000	4,750	36.4
F-3	13,400	5,479	40.9
F-6-L	13,514	5,755	42.6
NC-2	22,600	8,900	39.4
NC-4	28,000	12,000	42.8
Tarrant	44,862	18,745	41.8

In this comparison, I have not labored the point as to whether a large seaplane or a large landplane is more advantageous. Without burdening the paper with further tables, I can state that there is essentially no difference between them. The large landplane can be made somewhat lighter structurally than the flying boat, but due to the necessity for providing a slower landing speed the wings must be larger and, hence, heavier. The net result is practically to make the types equivalent in large sizes.

To revert to the comparison with airships, we have the flying boat's power proportional to total weight or to L^3 and, likewise, the useful load or margin available to carry fuel. Consequently, the endurance which is the quotient of these quantities is independent of size and remains constant so far as the effect of size alone is concerned. Practically, the larger flying boats do, however, have a somewhat greater endurance, but this is not due to size but to greater refinement in design. With very large boats it is possible to increase slightly the efficiency of propulsion by using geared-down propellers of large diameter and by more careful reduction of resistance to propulsion. Also the weight of crew and navigational equipment in a large boat is a smaller proportion of the total lift. All economies taken together may give an increase of some 30 per cent. in endurance. No further substantial increase can be expected without material improvement in weight and economy of engines. Naturally, such improvements are expected but cannot be counted on to-day in a design to be built to-morrow. Mere size is not itself going to give great endurance.

On the other hand, we saw how the endurance of the airship increased at least as rapidly as the length. To get greater endurance we need only build larger and, keeping the speed constant,

we get automatically relatively enormous increases in endurance.

We can conclude from all this that for Fleet Scouting at sea where long distances are covered, the rigid airship will be the only suitable type of aircraft. Where the distances to be covered are not too great, where the winds are high, and where hostile aircraft are numerous and efficient, the rigid airship yields first choice to the large flying boat of the "Giant" type, to use the word applied by the Germans, to their 1918 machines.

For daylight patrols over coastal waters a large flying boat is more useful than an airship because a greater area can be searched in given time and because less affected by weather. However, it is often cheaper to use a large number of moderate size flying boats for short patrols.

For convoy work, the flying boat is altogether too fast and of too short endurance. To keep in company with a convoy of vessels proceeding at 10 or 12 knots, the airship is most suitable and for this duty a large number of the cheaper non-rigid airships is more economical to employ than the more costly rigids. The latter should be reserved for Fleet Scouting.

The ship's fighting plane must be carried aboard ship and hence is as small and compact as possible. It is mounted on a platform over a turret and when the ship steams into the wind, the plane flies off in a run of some 40 feet. To be sure of getting off, the plane must be light with relatively large wings. The Army fighting planes are not at all suitable for this work, because they require a long run to get into the air. Furthermore, the Navy ship's fighting plane may have to land in the water in case of engine failure. To permit this, the planes are fitted with emergency flotation gear consisting of vanes, to keep the plane from somersaulting, and air-bags inflated from a bottle of compressed air carried in the plane. Normally, the air-bags are tightly rolled up. The air-bags and vanes are provided instead of regular pontoons to save weight. The fighting plane cannot return to her parent ship directly, but must land on the deck of a special flush deckship called a "Carrier."

The ship's spotting plane is similar to the fighter, except that it is a two-seater of less speed and greater endurance. It is to some extent a general utility machine, and provided with guns to fight off hostile aircraft. The spotting plane may be either a land machine with air-bags or a seaplane.

The torpedo and bombing plane is a larger machine equipped to carry heavy bombs or a torpedo. It will be launched from the carrier. The development of the torpedo plane and the tactics involved in its employment, I am not permitted to discuss in detail. It is, however, a very important type and peculiarly Naval.

I have not yet mentioned the Kite Balloon, which while less interesting technically, is of great importance to the Navy. The Kite Balloon is towed from a ship at an elevation of about 1000 feet. At such elevation, a spotter can control the fire of the ship's guns unless an enemy smoke screen interferes. In that case, the planes must be depended upon. One may ask, why not depend on planes all the time? The answer is: communications. The communications between a plane aloft and the firing ship are by means of radio or some visual signal. At best such signals are difficult to keep clear and when there are many ships firing and many planes aloft, the chances for confusion and interference are very fair. The Kite Balloon observer has a telephone directly to his ship, giving him freedom from interruption and interference.

I have gone into the realm of prophecy a bit in connection with the problem of the rigid airship *vs.* the large flying boat, because this is a real problem now under discussion. A decision cannot be reached from a consideration of the two types as they exist to-day, as each is certain of further development. So far as such development can be forecast, the advantage appears to lie with the rigid airship.

The other Naval types mentioned involve no such fundamental difficulty as a selection of the type best worth developing. The ship's fighting and spotting planes are adaptations of planes brought out during the War. The medium-sized plane for coast patrol is fairly satisfactory as it exists at present. It was perfected during the War for antisubmarine work.

Similarly, the non-rigid airship for convoy duty is well developed, both in the United States and abroad, and no important changes in type are anticipated.

In general, the line to be followed in the design of Naval Aircraft is fairly clear. As the special types needed to meet Naval requirements become more highly specialized, their difference from the aircraft used by an Army will become more marked. Already, a Naval Aviator has come to be regarded as a Naval Officer first, and an aviator second.

DESTRUCTION OF FRENCH COAL MINES AND PLANTS AND THEIR REHABILITATION.*

BY

GEORGE S. RICE.†

Chief Mining Engineer, Bureau of Mines, Department of the Interior.

When the German Imperialists planned their campaign for military and industrial dominion of the world, they did not indulge in the idle dream, that it could be accomplished by purely military means, but carefully studied their successive steps with reference to constant support of their military power by commercial development.

Large resources of coal and iron have led to the commercial greatness of countries possessing them. Agriculture is most important, but is not alone sufficient, as railroads must carry the product to market, and in turn coal and iron are essential to transportation. The ownership of the iron ore alone is not sufficient. Sweden, for example, has splendid iron resources but has had to export its raw product to other countries to be worked up into merchantable iron and steel, and hence it has not reaped the full benefit because it has not possessed coal. On the other hand, take the countries which have been most prosperous commercially in the past hundred years. They are the countries that possess important iron and coking coal resources: Great Britain first, in period of development, Germany next, and

* Presented at a meeting of the Mining and Metallurgical Section held Thursday evening, December 4, 1919.

† The author was a member of a Commission sent by the Secretary of the Interior to France to investigate developments in mining and metallurgy under stress of war conditions, and also to observe the extent and character of the destruction of the collieries and the steel and iron plants, and methods which were being taken to re-establish them. This commission consisted of Dr. F. G. Cottrell, Chief Metallurgist of the Bureau of Mines; Mr. Frank H. Probert, Dean of the University of California Mining School; and Mr. George S. Rice, Chief Mining Engineer of the Bureau. While conducting this investigation Mr. Rice made a trip to the Saar Basin to observe the conditions there. Subsequently Mr. Rice acted as adviser on mining matters to the Representative of the Economic Council in an Interallied conference held at Cologne in April, 1919, and afterward visited mining districts in central and southern France, in Belgium and Great Britain.

then the United States, the latter having by far greater resources of coal and iron than any other country in the world.

IRON RESOURCES OF LORRAINE.

France, prior to the war of 1871, possessed the iron ore of Lorraine (termed minette ore) which in 1871 was not considered

CHART I.

Map of coal and iron basins of Western Europe.

so valuable on account of the high phosphorus content. This prevented its use in steel making, limiting its employment to castings. Nevertheless by the advice of German technicians, Bismarck took from France all the iron deposits then known in Lorraine. Later in 1878, through the invention of Thomas

and Gilchrist of their dephosphorizing process, this ore, although low grade as compared with the hematite ore of the Lake Superior district, became most valuable to Germany's industrial development.

French development companies undertook to trace the ore deposits westward from the boundary of 1871, by deep prospecting bore holes, and established the fact that the minette ores, which are found interbedded with the limestones of the Paris basin outcropping in German Lorraine and Luxemburg and dipping eastward, extended into France. Later it proved there

FIG. 1.

Loos Battlefield on Lens concession, Loos and twin towers of Lens No. 15.

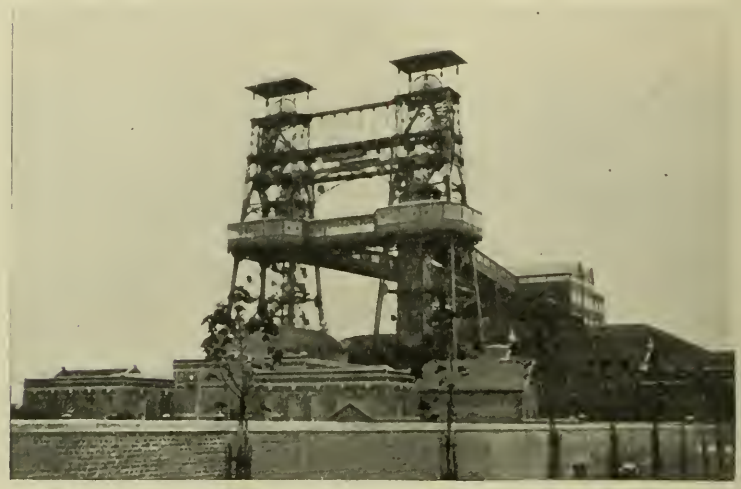
were greater iron ore resources in French Lorraine than in "Lorraine Annex." The basin, as a whole in Germany, France, and Luxemburg, produced 55 million tons of ore in 1913. Although the ore is low grade, carrying on the average only about 33 per cent. iron, it is easily smelted and formed the basis of vast industries in Germany and to a lesser extent in France.

IMPORTANCE OF COAL IN DEVELOPMENT OF IRON.

France, unlike Germany, is somewhat deficient in coal resources, and the natural mining conditions make it difficult to obtain large outputs from the coal basins. Coking coal is the most important factor in the utilization of iron and the shortage of this has in the past tended to restrict the industrial expansion of

France as compared with that of England, Germany, and the United States. Germany having iron ore (until the end of the war) and, what is still more important, having abundant and comparatively cheap coking coal was second only to the United States in its industrial development. In the United States, we have the greatest resources in coal as well as iron, and heretofore our coal, which is shallow and easily mined, has been

FIG. 2.



Twin towers of No. 15 before the war.

very cheaply produced and this has enabled us to make enormous strides commercially.

GERMAN DESIRE TO EXTEND IRON AND COAL POSSESSIONS.

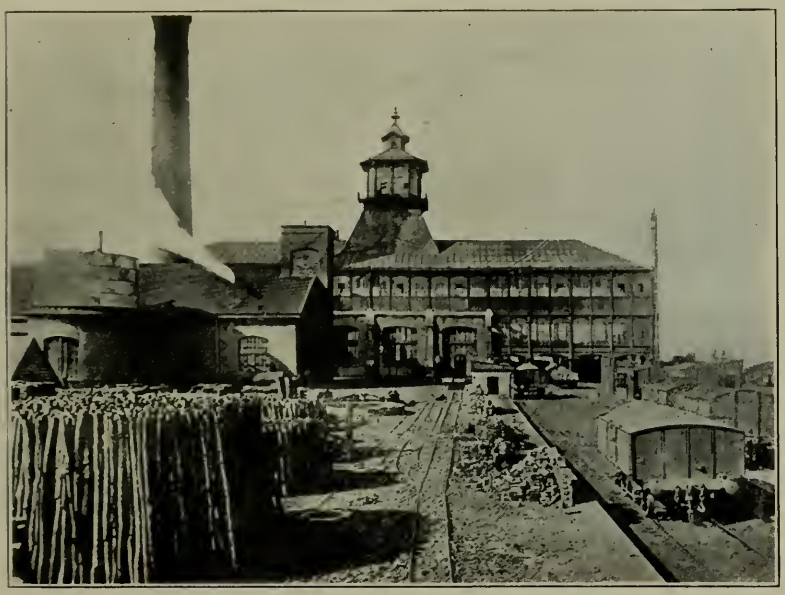
Germany before the war did not produce all of the iron ore which it used. It imported nearly half of its needs,[1] chiefly from France and some from Sweden and Spain. Even before the war, German iron masters hinted that Germany should have the balance of the minette iron ore deposit of Lorraine. After

[1] Germany's production in 1913, including Luxemburg, with which it was tied commercially, was 35,373,000 tons of iron ore. It imported 14,019,000 tons from France, Spain and Sweden, and exported 2,600,000 tons. It used about 47,000,000 tons in 1913.

the war started, while declaiming to the world that they were on the defensive, the German iron masters openly urged the government to make permanent their control of the Briey iron district of French Lorraine which German armies seized when they crossed the border in July, 1914.

While Germany has splendid coking coal resources in its Westphalian field and greater resources in such kind of coal than possessed by any other European countries except England,

FIG. 3.



Lens No. 5 mine before the war.

if the Germans were to hold Belgium, and the north of France, as the Imperialists desired, they would need local coal in those occupied territories. Moreover they wanted coal closer to the seaboard, for bunkering their ships or for exporting, than that produced in Westphalia, which is many miles from their seaports. Mines centering around Dortmund are about 118 miles to Bremen by railroad and 168 miles to Hamburg, whereas the centres of the Belgian field and the Pas-de-Calais coal field of France are only about 50 and 60 miles, respectively, from channel seaports.

The coal of the Belgian field, while in part coking, is mostly

of the steam or semi-anthracite character which would be excellent for bunkering ships. If one examines the map (Chart I) he will notice the great iron basin of France and former German Lorraine is as close to the Westphalian field as to the coal fields of northern France which also contain considerable good coking coal. The Saar coal field is still nearer the iron basin, but as yet only a limited amount of coking coal has been produced—

FIG. 4.

Lens No. 5 mine, destroyed by battle.

only a few million tons per annum out of a total production of 17,000,000 before the war.

GERMAN DESTRUCTION OF FRENCH AND BELGIAN INDUSTRIES.

For the fullest development of its imperial policy, Germany therefore sought to seize the coal and iron of France and the coal of Belgium. Unexpectedly the war was prolonged and when, following the British drive in the Somme in 1917, the Germans evidently began to doubt their ability to hold Northern France and Belgium, they planned the campaign of industrial destruction. Until that time, the destruction other than the relatively small amount of wreckage from military operations,

had apparently been by unofficial pillage. The campaign then planned was as merciless as it was methodical. All industries in Belgium and France were marked for destruction with two notable exceptions—the iron mines of French Lorraine and the coal mines of Belgium. Both came through practically without injury except some unintentional injuries in the case of the French iron mines through bad mining, that is: in certain mines worked by the Germans, who used prisoners, chiefly Russians, the pillars were robbed, which allowed roof falls to occur, and

FIG. 5.

Liévin miners' village before war.

this resulted in material damage. Other than this the only damage was the taking of copper trolley wires from underground electric roads and substituting iron wire therefor, and some destruction by explosives and burning of miners' villages.

ESCAPE FROM DESTRUCTION OF FRENCH IRON MINES AND BELGIAN COAL MINES.

The reason for the general immunity of the French iron mines is manifest: Germany needed the Briey iron ore. If it could defend this against the owners, as it did until the armistice, so much the better. If not, it would still require to get the iron ore by import for the continuance of its Westphalian iron and steel

industries: The need of Westphalian coal it probably considered its hostage to compel sending minette ore from France.

As concerns the escape from destruction of the coal mines of Belgium, the reason is not altogether clear, but there was nothing to indicate from other matters that it was due to any mercy on the part of the Germans. It was thought that it might have been due to the warning given by President Wilson that such destruction would bring upon them measures of retribution, at

FIG. 6.

Liévin miners' village after bombardment.

a time when they were losing the war. However, this warning did not save the adjacent French collieries whose wrecking proceeded to the day of armistice; on the other hand their escape might have been due to the fact that Belgium produces little coking coal and has no iron ore and hence its iron and steel industry could not be really competitive with the great Westphalian steel and iron industry.

DESTRUCTION OF STEEL AND OTHER INDUSTRIES OF BELGIUM AND FRANCE.

In striking contrast to the immunity of the French iron mines and the Belgian coal mines there was as complete systematic

destruction as possible of all other industries of Northern France and Belgium with the manifest intent to cripple France for years to come. Then if given free rein German factories entirely uninjured by the war and ready to start up, would go ahead and dominate industrially where conquest could not come in a military way. Thus, without the restraints of the Treaty of Peace, Germany would essentially have won the war. Even with the loss of Lorraine Germany would have won industrially and in compara-

FIG. 7.

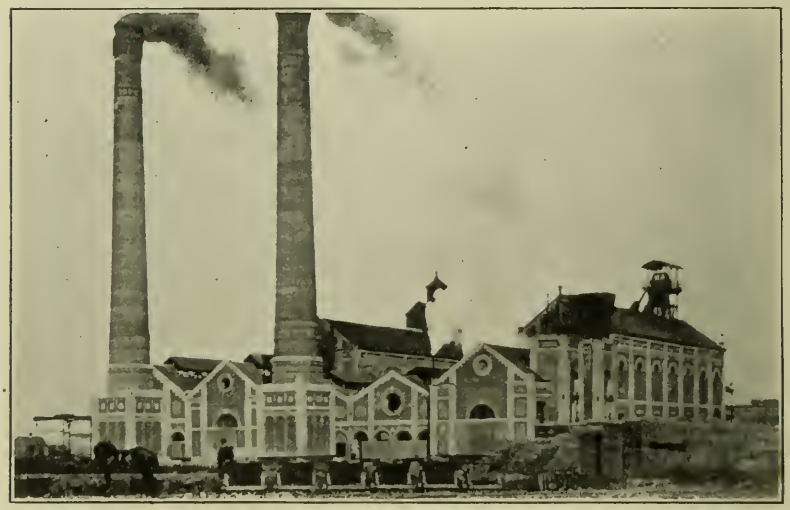
Liévin No. 4 hoisting engine, destroyed by Germans.

tively few years would have been able to strike again, and this is what France feared and still fears. The writer was in Northern France in 1908 and in 1911 and his observation then was that the mass of the French wanted peace almost at any price and were willing to let the losses of 1871 be forgotten.

While the area covered by the German advance did not comprise more than 7 per cent. of the entire territory of France, yet as pointed out by the late Colonel Edouard de Billy, head of the French High Commission, these invaded districts were the most developed industrially. From them came 30 per cent. of the industrial output of the country; 90 per cent. of the iron

ore; 83 per cent. of the pig iron; 75 per cent. of the steel; 70 per cent. of the coal; 94 per cent. of the combed wool; 90 per cent. of the flax; and 65 per cent. of the sugar. They produced four-fifths of the woolen wear and included 80 per cent. of the weaving industry. The Germans robbed the plants of their machinery, and structural steel and iron were cut up and taken to Germany for reworking. The mines were flooded, surface plants dynamited, workmen's buildings and farm buildings destroyed and agricultural machinery destroyed or carried away.

FIG. 8.



Liévin No. 3 mine before war.

It is true that some of the destruction of the mines was due to battle and from military needs, but this kind of destruction probably did not represent more than a few per cent. of the total destruction. The steel plants and the industrial plants were in most cases miles behind the lines, but their wreckage was just as complete in effect, though not so spectacular, as that in No Man's land.

DESOLATION CAUSED BY GERMANS IN FRANCE.

The attempt to make the invaded provinces of Northern France a desolate region was very striking, especially in contrast with the treatment of Belgium after the first savageries. Probably it was due to the cold-blooded calculation that Belgium was

not a serious industrial competitor, whereas France was. Belgium, outside of the limited battle area and destroyed blocks or isolated buildings in some of the cities, as at Liege and Louvain, where the Germans wished to strike terror to the hearts of the inhabitants, was physically damaged to small degree. The repression of the people by harsh methods made life by no means easy, but the conditions were in striking contrast to Northern France last winter, where one might travel for miles without see-

FIG. 9.

Liévin No. 3 mine, destroyed by battle.

ing a living being, only demolished or uninhabitable villages and cities, often mere piles of brick and stone. Even in the larger cities of the coal fields outside of the battle area, as in Valenciennes and Douai, blocks of houses had been destroyed without apparent reason and thousands of humble dwellings burned or blasted with dynamite. The pillage extended to banks and private property. For example, the writer visited a bank at Douai in Northern France. The president showed to him the safety deposit vaults under the bank. All the doors of the security boxes and safes had been neatly cut out by an oxyacetylene

torch. Not only had all articles of intrinsic value been removed but even the papers had been taken and sent to Berlin, nominally, for safe keeping. One can well imagine the difficulties of straightening out the titles to property in the invaded provinces for years to come.

The people in these French provinces suffered more from lack of food than those in Belgium. The writer was told the Germans prevented Hoover's men from distributing the food in France, insisting that it be done through the German military authorities, which of course meant the inhabitants were robbed of their full rations. They looked anemic as compared with the Belgians.

DESCRIPTION OF THE PAS-DE-CALAIS AND NORD COAL BASIN.

Although France has 50 separate and somewhat scattered coal fields, most of them are quite small and of local importance only. By far the most important is the Valenciennes basin in the northeast corner of France and this is divided into the Pas-de-Calais and Nord districts. Often the field is spoken of as the Pas-de-Calais field and since the war is usually known to Americans as the Lens field on account of the terrific struggle around the city of Lens.

The basin is a continuation of a long narrow geologic trough lying east and west. Easterly it extends through the south part of Belgium and the following well-known industrial centres are found successively in going east along its course: Mons, Charleroi, Namur, and Liege; thence it passes into Germany at Aix Le Chappelle. Going westerly from the French-Belgian border, it extends in France through Valenciennes, Douai, Courrièries and Lens and then northwesterly through Béthune, all names being made famous by the war. A narrow off-shoot of the coal field extends westwardly through Bruay and Marles and thence to Fléchinelle. It was this extension of the field that was not invaded, and by intensive working the French succeeded in greatly increasing the output of the collieries in this part of the extension in spite of long-range bombardment.

GEOLOGIC AND MINING CONDITIONS

The coal is of Carboniferous age and in character ranges from long-flame bituminous coal to semi-anthracite with a fair portion of coking coal. Where all the beds are present there

are 90 coal beds with an aggregate thickness of 250 feet, but generally not over two-thirds of these beds are present at any one point and many of them are not of workable thickness, the total thickness of the workable coal usually being not over 150 feet. Most of the beds are less than 3 feet in thickness. In some instances two beds unite giving locally a thickness of from 9 to 12 feet. There may also be a local thickening of the bed due to the folding back of a seam. At Lens where the conditions

FIG. 10.

Béthune No. 11 mine, destroyed by long range bombardment by Germans.

are typical, the total coal thickness of the measures is 4300 feet with 51 workable beds present containing 154 feet of coal.

The geologic structure is very complicated; subsequent to formation of the coal measures there was a great geologic thrust from south to north crumpling up the measures and producing sharp overturned folds and overthrust faults as well as cross faulting. Rocks of Devonian age have been thrust over the coal measures on the south side of the basin. The general strike of the rocks, subject to many local changes, is east and west and the normal dips which are usually steep, 20 to 40 degrees, are to the south.

After the upturned measures had been planed off by long continued erosion, they sank below sea level and chalk and marls have been deposited over the upturned edges. Then the strata lifted and these chalks and marls were slightly raised above the sea level. The surface over the basin is generally flat, rising to the south in low hills or ridges, one of the most prominent ridges south of Lens being the famous Vimy Ridge which commands a wide view over the basin. Here military mining was extensively done by the Germans and British, and the British thrust back the Germans in 1917. The superficial dimensions of the basin are 62 miles in length from the Belgian border and in width varying from 2 miles up to 10 miles at Lens. The entire superficial area covers about 405 square miles. This does not include the Belgian part of the basin.

KINDS OF COAL AND PRODUCTION

There are wide differences in the composition of the coals, the variation in the volatile combustible content ranging from 7 to 40 per cent. High volatile coal is found in the outcrop coals along the north margin, the volatile matter ratio decreasing toward the south margin, where the coals lie deeper.

Of the 26 million tons (metric) produced in 1911 there were 4 million tons or 15 per cent. of semi-anthracite, 3,900,000 tons or 15 per cent. non-coking or semi-bituminous; 11,200,000 tons or 43 per cent. of coking and gas coal; and 6,900,000 tons or 27 per cent. volatile or splint coal. In 1913 the total production was 28 million tons.

The coal is of good quality but is generally friable in character. It is low in ash after the careful cleaning given it, which is done by numerous pickers and by washing the small coal. The moisture content is low. The steam coal, when briquetted, makes a splendid steamship fuel. All coke is made in by-product ovens; 2,873,000 tons of by-product coke was produced in 1913 out of the total production for France of 3,667,000 tons.

There were 50 extraction pits or shafts in the Nord district and 100 in the Pas-de-Calais besides numerous auxiliary and ventilating shafts. An average of 7 to 8 beds was worked from each pit. The average depth of extraction, that is, the average depth of coal hoisting, was about 1200 feet, and the deepest hoisting from any pit was 3300 feet.

MINING PLANTS AND DEVELOPMENT

The equipment and development of the mines was very high class in character. It may be said that there were no finer mining plants in the world than those of Northern France. Steel pit head frames, architecturally attractive; substantial and fire-proof tipple and screening buildings; splendid hoisting engines, chiefly electric in the largest plants; well-designed fans which

FIG. 10a.

Béthune mine No. 11 before the war.

were always in duplicate; and other power and labor-saving equipment of the best type.

Those mining concessions possessing coking coal had by-product oven plants and central power stations using the surplus gas and supplying the respective concession with electric power for the different mines on the concession. In the case of the Lens collieries, which had the largest production of the basin, the central power station furnished electric power for canals and other public utilities for a distance of 100 miles towards Paris.

As regards housing, the miners' dwellings in the ancient towns, although constructed of brick and stone, did not have

modern improvements, but the more recently constructed dwellings and other buildings in the mining villages, all now destroyed, were made very attractive, and much attention was given to sanitation and sociologic features.

Practically no wood was used in the construction of colliery buildings; steel and brick were generally used for framework and walls, and the roof coverings were of tile and glass supported by steel girders or arches.

WATER-BEARING MEASURES PENETRATED BY SHAFTS.

As the coal measures are generally overlain with water-bearing marls and chalks, in some places with quicksand, ordinary shaft-sinking methods were often impracticable on account of the great flow of water, and many of the shafts were sunk by the freezing process. In more recent years the method of prior cement injection through bore holes surrounding the shaft was employed. The shafts are lined through the water-bearing strata with iron curbing rings and through the rock with brick, or concrete. Usually a single colliery has only two shafts, both equipped for hoisting, the air shaft usually being used for lowering supplies and hoisting and lowering men. Sometimes both upcast and downcast shafts were used in hoisting coal. Underground connections were made with other collieries of the same concession and since the Courrières disaster (1906) and M. Taffanel's coal-dust explosibility investigations (1907–1914), such connections had been especially designed with explosion stopping arrangement and equipped with special "shale-dust barrier" devices. Some of the shafts hoisted coal from several levels, but usually the hoisting was done in balance from one landing level, the coal being assembled from levels below or above by hoisting or lowering in underground shafts.

MINING METHODS.

Owing to the disturbed conditions of the coal beds, the underground method of development is entirely different from that which prevails in the United States, the main levels or gangways are driven across the strata, that is, at right angles to the strike of the coal beds, and when a coal bed is cut, it is blocked out by "entries" and "slopes" or "raises" in the bed. Owing to the large amount of extensive cross-cut tunnelling and uncer-

tainty regarding local changes in the beds, the Government laws permit the driving of long advance or exploratory tunnels singly, the ventilation being obtained by use of large metal pipes in connection with a suction fan placed at the mouth of the heading and operated by a small compressed-air engine, electric motors not being permissible on account of the danger of igniting fire damp. The ventilating pipe is made of rivetted galvanized iron sheets 12 to 20 inches in diameter. This method of development, in comparison with double entries required by the state laws of this

FIG. 10b.

Béthune No. 11 safety lamp house before the war.

country, appears to be safe, as under the French law a working coal face cannot be developed from a single heading; hence no pockets are made in which fire damp might accumulate, but development must await connections being made with the next level above in order to obtain a circuit of air. A further excellent safety requirement is that ventilation must always be ascensional, that is, the intake must enter on the lower level.

LONGWALL METHOD AND PACKING.

The longwall system is used in working the coal, the faces, usually in steps, the lowest being in advance, are parallel with the dip. The "goaf" or excavated space must be entirely filled

and well packed with rock and refuse. As the roof is generally a weak shale, extensive timbering is required and this is done with unusual care in the north of France, a forepoling system of support at the face being employed. The filling and the pack-wall material is rock obtained in driving the cross-cut tunnels and from brushing in the gangways. As there is usually a surplus of rock obtained in mining the thin beds this surplus is taken into the workings of thicker beds. Where there is insufficient rock or debris for filling and packing some must be sent from the surface. At a number of collieries the hydraulic or flushing system was being employed, using washery refuse and cinders. In later years some sand for hydraulic filling had been brought from the seashore.

Where there is local thickening of the coal, special mining methods are employed such as the use of square sets and a back filling method similar to that used in metal mines. The writer saw this method being used before the war in one of the Courrières collieries where the coal, due to a fold, is locally 40 feet thick.

The main entries of the levels are closely timbered and in the permanent main haulage-ways brick and concrete archings are extensively used. Miles of light reinforced concerete lining had been constructed in Béthune No. 11, one of the destroyed collieries.

GAS AND DUST PRECAUTIONS.

As might be expected in deep deformed coal measures, the mines are generally gaseous and safety lamps are required. Hand storage-battery electric lamps were used to some extent. On the whole, except in some of the deeper "pits," the mines are not as gaseous as those in Belgium, and ventilation methods are especially good. The French companies were perhaps the first to adopt, years ago, the modern method of systematic daily analysis of the returns of airways, in order to obtain definite information for the control of ventilation.

Until the great Courrières disaster of 1906 in which 1100 men were killed, the French engineers because of laboratory tests held the opinion that coal dust in itself would not propagate an explosion, but this disaster changed their point of view; following it extensive experiments were begun under an investigative bureau established by the Central Committee of Collieries of France.[2] The

[2] Comité Central des Houillères de France.

experiment station was located at Liévin in the Pas-des-Calais, with Col. J. Taffanel, one of the Government mining engineers, in charge. The coal dust explosibility investigations conducted by Colonel Taffanel were basic in their findings and were of the utmost value to the author in carrying on parallel testings at the Experimental Mine of the Bureau of Mines, at Bruceton, Pa. The Liévin experimental station was on the battle line early in the war and was totally destroyed.

FIG. 11.

Béthune No. 8 mine destroyed by battle. Alternately in possession of British and Germans.

TIMBERING AND INSPECTION.

Great precations were taken by the French in mining, especially as regards timbering. Except for the year of the Courrières disaster their record rivalled that of Belgium for the least number of lives lost per thousand employed underground, the yearly rate being about one per thousand employed. This is nearly fifty per cent. less than obtained in either Germany or Great Britian and one-third the rate of this country. Such a low death rate from accidents was the result of the operators not sparing expense and the governmental inspection being rigid. The inspection service is in the hands of highly trained mining engineers assisted by "miners' inspectors."

COMPARISON OF PRODUCTION PER MAN, FRANCE AND AMERICA.

The production per man in France, as in Germany and Great Britain, is low compared to that in the United States, but this is not, as sometimes is assumed, because the workmen in this country are better than those of France but is chiefly due to machine mining. In this country the bituminous coal beds as worked average thicker, lie level, and the conditions are regular, making the extensive use of mining machines both possible and profitable.

FIG. 12.

Béthune No. 8 cratered shaft, blasted by Germans.

In France the pitching and irregular character of the coal beds and the poor roof prevent the extensive use of undercutting machinery and in most cases it is not needed as the coal is soft or spalls off under heavy pressures. However, mechanically shaken loading chutes are used at the longwall faces where the grade is too flat for the coal to run unaided. Secondly, the requirement that thin coal as well as thick coal must be mined, necessitates a large amount of dead work. The third important factor is the requirement that the workings shall be packed to prevent subsidence and this may frequently be very costly, as the packing material generally has to be sent to the mining face and it may have to be quarried or excavated on the surface. Fourth, there are no

FIG. 12a.

Another view of the cratered shaft of Béthune No. 8 mine.

chances taken in questions of safety, especially timbering. In this country, although the mine roofs are almost always stronger, our accident rate from falls is vastly greater than theirs. Falls of rock and coal represent 40 per cent. of our coal mine accidents.

MINER'S PRODUCTION AND EARNINGS.

The average production for an underground employee per annum in the Pas-de-Calais field was 300 tons (metric), and per working day about 1.1 tons.

Prior to the war the miners working at the face averaged about 7 francs or $1.40 pre-war exchange, per shift of eight hours. The boys, drivers and helpers were paid 5 to 6 francs ($1.00 to $1.20); all inside labor averaged $1.20 per day. The age limit of the boys employed underground was 13 years.

FIG. 12b.

Overturned head frame of Courrières No. 6 mine. Systematic destruction.

MINE OUTPUTS, SELLING PRICE AND COSTS.

The colliery which had the largest output of coal and coke of the basin was the Lens Company which produced about 4,000,000 tons (metric) annually. Next in point of output were Anzin and Courrières, each of which produced over 3,000,000 tons. Then followed Béthune and Liévin producing about 2,000,000 tons each. The underground labor cost in the basin was reported to average about $1.10 per ton. Including surface labor the total labor cost of coal delivered on railway cars was about $1.40 per ton. The entire operating cost, including supplies, superintendence, and other items, of placing coal on cars was from $2.20 to $2.50 per ton. The average selling price of the coal at the mines preceding the war was 16 francs, or about $3 per ton. The gross profit,

FIG. 13.

Courrières No. 9 cratered shaft, destroyed by Germans. Mine far behind battle line.

not including the income tax, was from 60 cents to $1 per ton. This profit was on the coal and did not include coking and by-products profits.

The number of work days per year averaged 300, and the average production per hoisting shaft per annum was about 75,000 tons.

The mining companies did not own the coal but received concessions from the Government, paying a nominal rental of 10 cents per hectare (2.471 acres). The principal taxes are collected from a percentage of the net earnings, and prior to the war the tax was 6 per cent. of the earnings available for dividends.

POST-WAR LABOR WAGES.

As in this country, during and since the war the wages paid labor had doubled or trebled. Last April the Courrières Company, which was then one of the companies most actively engaged in cleaning up, was paying 14 francs per day to ordinary workmen, one franc additional being allowed to men with a family, and 17 francs ($3.66 pre-war exchange) for skilled workmen.

In the Bruay colliery to the west of the battle line, which was operated intensively during the war, the miners were earning in April from 15 to 18 francs per day, general underground laborers being paid 12 to 14 francs.

PRODUCING MINES IN PAS-DE-CALAIS DISTRICT

There were only one-half a dozen collieries left to the French to produce coal at the west end of the coal basin. Their production, by concentrating miners in them, had been raised from 2400 to about 3800 tons per day. In 1915 the production of this area was 7,382,000 tons. In 1916 it had been raised to 8,195,000 tons and in 1917 to 11,450,000 tons. In 1918 some additional mines in the vicinity of Bèthune were lost by the advance of the German lines in their spring drive and the total output for this end of the field was probably a little less than in 1917.

Following the armistice the output lowered 15 to 20 per cent. on account of the miners leaving for their old homes and the collieries dropping from 3 eight-hour shifts per day to 2 shifts of eight hours.

HISTORICAL REVIEW OF THE DESTRUCTION OF THE COLLIERIES

Through the kindness of the Central Committee of the Collieries of France (Comité Central des Houillères de France) [3] I received data giving chronologically the progress and character

[3] A permanent organization of all French collieries for coöperative investigations in the coal industry. Before the war it maintained a safety investigative bureau at Liévan in the Pas-de-Calais, of which Col. J. Taffanel was director.

of the destruction of the collieries; from that and from data secured during my visit the following story was written November 29, 1919.

The invasion of the field in August, 1914, by the Germans began immediately after the retreat of the British from Mons, southward toward Paris. Mons is in the Belgian coal field about 10 kilometres (six miles) from the boundary between Belgium and France. On the 24th of August the concessions in the vicinity of Valenciennes had been occupied. By October 1, the invasion

FIG. 14.

Boilers at Courrières No. 9 with holes in domes, holes also being blasted in bottoms of boilers.

had spread to the concessions in the vicinity of Douai, and by October 6, Lens and Liévin had been occupied.

During the first invasion, until the stabilization of the fronts at the end of October, the destruction was carried on under plea of military precaution against the utilization of the pits near the firing line by the allied armies. It consisted of the destroyal in some of the mines of the means of extraction and of communication between the bottom and the surface, such as cutting the cables and throwing cages and buckets to the bottom of the shafts.

During that period stores, provisions, timbers, and locomotives were seized, and there occurred a certain amount of pillage and unauthorized destruction on the part of the rank and file.

At that time there was no real excuse for the destruction as there was no fighting except for a few hours in the streets of Billy-Montigny and Drocourt. At Courrières and Lens, in the first days of the occupation, the German military authorities forbade all work of maintaining the bottom or the pumping of water. Of course no Frenchmen of military age remained in the district, all having been mobilized at the outbreak of the war, but old men, women, and children largely remained as the invasion was too rapid for the general escape.

STABILIZATION OF BATTLE LINES.

Upon the stabilization of the lines the trench warfare began and at the end of October the front line of the trenches passed through the concessions of Douvrin, Béthune, and Liévin. The Lens concession was in the range of the allied heavy artillery. With the exception of these concessions, which were exposed to the bombardment of both sides, during the second period which lasted until the conquest of Vimy Ridge by the English in 1917, the destruction by damage resulting from the operations of war was comparatively small. Meantime during this period there was continued removal of the apparatus, stores, and provisions without requisition orders, or in some cases with orders for quantities much less than were taken away, and at low values.

At Courrières, for example, mine wood was taken to the amount of 4 million francs value at that date, and 1600 wagons were removed for which the enemy gave requisition for 100 wagons.

At Carvin, which lay far behind the firing line, wagons and electric wires were removed and there began a general seizure of copper from all kinds of machinery which were destroyed in obtaining the copper. The German military regulations forbade the companies to have their workhouses and pits examined at night. It was during the night that most of these removals were effected, so that the Germans would be able to refuse requisition orders.

TREATMENT OF LENS COLLIERIES. FIRST PERIOD OF DESTRUCTION.

For the Lens collieries special treatment was reserved. Up to September 25, 1915, these mines had suffered comparatively little by the enemy occupation except for repair work underground, the usual daily examination of the pits being prevented.

FIG. 15.

Courrières No. 21 new unfurnished plant partly demolished, showing holes made in post for blasting. Sign marked 12½ Kg. (weight of explosive to be used).

At that time a big French-English attack furnished the Germans with pretexts for the severest measures. The British Army had taken the town of Loos and pit 15 of the Lens mine. This was one of the splendid new mines of the company, and its high head frames occupied a commanding position. The German command pretended to see the possibility of a means of communication between the English lines and the French population, who remained behind the enemy lines. Objections were raised by mine managements that there was no possibility of such communication as the mines had not been ventilated for nine months and moreover the shafts of the mines had been guarded by military guard during this period and nobody had entered. M. Reumaux, the managing director, suggested to the German military authorities that they completely seal at the bottom the outlets from one mine to the other and hermetically seal the shafts, leaving only small openings for escape of firedamp.

FLOODING MINES.

These proposals were submitted to a mission of engineers from the mines of Westphalia who, in spite of the obvious military security of the proposed measures, pronounced them insufficient; this of course was a mere subterfuge to give excuse for the fearful destruction. It was then ordered that the mines be inundated by blowing up the shaft lining and this was done in Lens pits 5 and 11. The inundation spread not only through the pits of the Lens concession but also through those of neighboring concessions at Meurchin, Liévin, Carvin, and Drocourt, rendering these workings useless for many years. This meant the loss to France for five years at least of 8 million tons or one-fifth of the national production at this time.

SECOND PERIOD OF DESTRUCTION. SYSTEMATIC WRECKING BEGUN.

Apparently in 1917 the Germans foresaw they must ultimately retreat, and began systematic destruction of surface installations heretofore untouched. Gangs of pioneers began to break up the surface plants and destruction of the steel headframes was prepared in advance to be executed at each pit as the Germans withdrew.

After the conquest in April, 1917, of Vimy Ridge, which lies to the south of Lens and overlooks the low-lying coal field,

resulted in placing the Lens concession in the firing line, there was fighting in and among the workmen's dwellings in Lens and surrounding villages; also part of the Courrières and Drocourt concessions came in the allied bombardment zone. Courrières collieries which had been in operation under control of the Germans were stopped and the neighboring population was evacuated. On April 13, the village of Henin-Lietard (Dourges)

FIG. 16.

Canal loading station of Béthune mines. This and barges destroyed in battle.

was also evacuated. The workmen's cities in the vicinity and surface installations at Drocourt pits 4 and 5 were destroyed by the bombardment.

THIRD PERIOD OF DESTRUCTION. COURRIÈRES MINES FLOODED.

In spite of advance of the front line of the British in 1917, the greater part of the Nord Basin to the East was still out of reach of the bombardment and consequently free from damage of military operations. Yet at this time everything was taken from Courrières mines and villages—even to hand tools and furniture, without military need. At Courrières 160 steam boilers were wrecked and, at Dourges, by means of explosives, the

machinery, trestles, etc., were destroyed. Then followed the blowing up of the lining of Courrières pit No. 9 and the flooding of the mines of this concession by water flowing from the quicksands and chalks. To hasten this process, the Germans ditched in surface ponds and swamps. The chief engineer of the Courrières Company informed the writer in April, 1919, that from sounding in some of the shafts, the company estimated there were 20 million cubic metres of water in its group of mines. The bulk of this water would probably have to be pumped from the depth of 1500 feet at least. Destruction during this period meant the loss of 4 million tons annual output to France.

In the spring of 1918 came the last German drive and while the British line held around Vimy Ridge and Lens, it was forced back into the vicinity of La Bassee and approached closely to Béthune, thus bringing the remaining Béthune mines under direct fire, and the mines at Bruay under long-range fire of the Germans. The last named was among the few important collieries left in working condition in the Pas-de-Calais field. However, while the long distance bombardment of Bruay did some damage it did not prevent continued operation of the mines, although there were grave difficulties in running trains and at one time this could only be done at night.

FOURTH PERIOD OF DESTRUCTION. FINAL WRECKAGE BEFORE GERMAN RETREAT.

The fourth and last period began with the final retreat of the Germans in September and extended to the date of the armistice, November 11, 1918. This retreat, which finally forced them back across the frontier beyond Mons in Belgium, was so rapid that little battle damage occurred after the opening phase which brought the mines in the vicinity of Douai into the firing line, but even at these mines the devastation was not so much from bombardment as from systematically planned destruction. This destruction all the way to the Belgian line had to be carried out in a very short time. It would seem that military fighting ought to have monopolized every effort of the Germans, yet during this final period the greatest damage was wrought in the shortest time by the enemy. The collieries that remained intact until the month of September, 1918, represented an annual extraction of nearly 8 million tons, or more than one-third of the total

FIG. 16a.

Canal loading station of Lens Collieries at Pont-à-Vendin, before the war.

production of the collieries invaded. For example, at the Aniche colliery on October 1, the extraction having been stopped the day before, three gangs of 75 pioneers began the devastation. On October 7 it was nearly completed. Eighteen mine shafts, including washeries, coke oven, railways, and bridges were destroyed.

Installations at the bottoms of the shafts were also destroyed, but to what extent was not known in May, 1919. Successively every mining plant was destroyed as the Germans retreated back to Belgium.

Hindenberg's order of October 15, forbidding destruction without military utility, issued as a result of the ultimatum of the United States Government, did not stop the systematic devastation even where no military needs existed. The Aniche and Anzin destruction was not completed until October 18 and Crispin, adjacent to the Belgian boundary, remained intact until October 28, when a battalion of pioneers arrived and proceeded to destroy totally the machinery and works. The German Captain (Edelmann) charged with the supervision of the mines, struck with the uselessness of the destruction he had received the order to carry out and probably uneasy as to his personal responsibility because of the American ultimatum, demanded and obtained from Ludendorff himself, the written order to continue the destruction.

SUMMARY OF DESTRUCTION

The Central Committee of France has set forth striking figures, which may be summarized as follows: The destruction of 220 pits and shafts belonging to 20 operating companies which were rendered unstable for several years; all surface installations were destroyed in detail. An annual production of more than 20,000,000 tons, or 50 per cent. of the production of all France in 1913, has been, temporarily at least, lost to the country. Unemployment was forced on 100,000 people and they and their families were reduced to extreme poverty.

Finally the Central Committee estimates that the material damage amounted to at least 2,000,000,000 francs in value (on a pre-war basis of exchange $400,000,000). This does not include the loss to France of at least 100,000,000 tons of coal production, for a period of 5 years, counting only the period of the war and the armistice, besides which there would be the loss of valuable by-products. So France to-day pays heavily for coal that it lost through the German occupation and destruction.

RECONSTRUCTION. TERMS OF TREATY OF PEACE.

Based on the terms of the Treaty of Peace the official French findings for the reconstruction of the mines evidently are that

it will take two to five years to get all the collieries in condition to hoist coal and at least ten years to get back the normal output of the basin. These terms are:

"Germany undertakes to deliver to France 7,000,000 tons of coal per year for ten years. In addition, Germany undertakes to deliver to France annually for a period not exceeding ten years an amount of coal equal to the difference between the annual production before the war of the coal mines of the Nord and Pas-de-Calais, destroyed as a result of the war, and the production of the mines of the same area during the years in question;

FIG. 17.

Canal at Pont-à-Vendin, near Lens coke oven plant, showing destruction by battle.

such delivery not to exceed 20,000,000 tons in any one year of the first five years, and 8,000,000 tons in any one year of the succeeding five years."

"The Allied and associated Governments interested may demand the delivery in place of coal of metallurgical coke in the proportion of three tons of coke to four tons of coal."

In the foregoing requirement it must be understood that the coal is not being furnished free by Germany but will be a profitable commercial transaction for the Westphalian operators as the price to be paid for the coal delivered at the French boundary will be the "German pit head price to German nationals" plus the freight to the boundary, or to the German seaport, "provided

the pit head price does not exceed the pit head price for British coals for export."

SAAR MINES TRANSFERRED TO FRANCE.

In this connection it may be well to clear up an erroneous impression that the Saar region has been finally turned over to France. Its mines have been, but not the sovereignty of the territory. The conditions imposed by the Treaty of Peace are these:

"As compensation for the destruction of the collieries in the north of France and as part payment towards the total reparation due from Germany for the damages resulting from the war, Germany cedes to France in full and absolute possession, with exclusive rights of exploitation, * * * the coal mines situated in the Saar basin * * *."

This includes undeveloped deposits whether belonging formerly to the Prussian State, the Bavarian State or private interests. The chief properties were the so-called Prussian fiscal mines, there being only a few privately owned mines, the owners of which will have to look to the German government for compensation. The fiscal mines of Prussia were acquired by that country in 1815 through the Vienna treaty of peace. In 1913 they produced 12,223,000 tons of coal. Several Bavarian mines included in the transfer produced, in 1913, 810,546 tons. The foregoing does not include the Lorraine portion of the Saar Valley field which was returned to France, the production of which in 1913 was 3,816,815 tons.

SAAR DISTRICT, PLEBISCITE.

While the ownership of the mines of the Prussian Saar basin thus passed to France permanently, the inhabitants of the Saar territory after a period of 15 years, are to determine by vote whether they wish:

(*a*) Maintenance of the regime established by the present Treaty.

(*b*) Union with France.

(*c*) Union with Germany.

CONSIDERATIONS IN RECONSTRUCTION IN FRENCH MINES.

Although to those not familiar with the conditions, the time for reconstruction indicated in the Treaty—10 years for complete

reconstruction and recovery of output—seems unnecessarily long, yet after one has traveled through the basin and reviewed the situation, taking into account the renewal of transportation facilities, the absence of adequate housing, the scarcity of building materials of all kinds, the requirement of fireproof and permanent construction of mine buildings, and has observed the frightful tangle of concrete, debris and twisted steel, he is prepared to understand the stupendous nature of the task. Besides

FIG. 18.

Aniche-Nord mine, systematically destroyed by Germans.

these physical difficulties, France to obtain maximum progress will have to purchase machinery and supplies from abroad which entails the serious problem of financing, with the balance of trade so much against her, instead of proceeding more slowly and constructing in France the needed machinery.

When the writer visited the mining district last April, the preliminary recovery work had been going on very slowly on account of the lack of transportation facilities. Reconstruction itself had not started at that time, only the main railway from Paris to Brussels had just been hastily reconstructed with temporary bridges; the branch lines still remained wrecked even

to the road bed, and all the bridges over the numerous canals and streams were down. The preliminary rehabilitation of the district is more difficult than the preliminary development of a new field because the tangled debris of steel, bricks and stone is in the way.

RECOVERING THE SHAFTS.

It had been suggested by those not acquainted with mining conditions underground that the old shafts had better be abandoned and new shafts sunk, but this would not be practicable until the shafts with blasted linings which permit the water to run freely into the mines have been repaired to exclude the water. When this most difficult task has been accomplished it would be advantageous in point of time and expense to accomplish the easier task of recovering the shafts through the 1000 to 2000 or more feet of rock strata to the former working levels and then obtain the benefit of all the expensive underground tunnelling and development. Although it is reported some demolition had been done underground, it was not thought likely by the French engineers that this damage was irreparable. Water has doubtless done great damage at the faces and in timbered sections, but it is thought the greater part of the extensive development is not badly injured.

No statements could be obtained from the local engineers as to the proposed method of engineering procedure, as they awaited the decision of an official board of engineers, but it seemed to the writer that the only way would be to boldly get at the work of recovering the cratered shafts by putting in new linings through the water-bearing ground, and that this might best be started by using through the débris large drop shafts, 25 to 30 feet in diameter, planned to telescope over the old lining where intact, using compressed air locks where the water pressure was not too great and where it was either the cementation process or the freezing process. There would of course have to be many special methods employed to meet the particular conditions. The broken steel and iron head-frames in the shaft craters will undoubtedly prove serious obstacles. An extensive use of oxyacetylene or oxyhydrogen torches for cutting up the twisted steel will be required.

HOUSING PROBLEMS.

One of the grave problems is the providing of dwelling places for the workers. Last April there had been many drifting back, pathetic little parties on foot, pushing or dragging their pitiful household remnants; more than the Government could properly care for. These had set up housekeeping in corners of ruins or in cellars. Providing a water supply for domestic use is another

FIG. 19.

Interior of power-house of Aniche-Nord, showing systematic destruction.

of the problems. The Government found it difficult last winter and spring to supply the people with even a small allotment of provisions on account of the lack of railroad facilities, and many army trucks had to be employed.

PURCHASE AND ALLOCATION OF MINE SUPPLIES.

In restoring the mines, as already stated, there was difficulty in obtaining machinery and supplies. The Government found it necessary in conjunction with the Central Committee of Collieries of France to establish a centralized office for the purchase of all materials needed in the reconstruction of destroyed indus-

tries, and this organization (Comptoir central d'achats industriel pour les regions envahies), which later came under the ministry of direct reconstruction (Reconstruction industrielle), purchases all materials and equipment and allocates them to the different industries and mines, but each mining company has been permitted to use its own discretion in the execution of the work of rehabilitation.

There has been reluctance on the part of the Government to permit purchase of machinery outside of France on two accounts; (1) rate of exchange, and (2) desire to avoid increasing the debt of France to other countries. However, it is expected that German mining machinery may be furnished as part of the reparation due from Germany. Many of the large electric hoisting engines and smaller equipment which had been destroyed were of German manufacture. While the French manufacturing establishments are able to turn out almost any kind of engineering equipment, and of a very high quality, these establishments cannot possibly cope with the present needs, and some of the French mining men consider that it would be better, in spite of the financial difficulties, to purchase American and British machinery and get back on a running basis as soon as possible.

The problems are very great but the French engineers are highly capable and need little help in the way of engineering advice. They know their problems better than we do, and while they appreciate the offers of engineering assistance, it seems to the writer that what they most need is financial assistance to support their own program of reconstruction.

In closing I cannot but express my great admiration for the splendid character of the French and their cheerful courage under the most fearful misfortunes that have ever come upon a civilized people in modern times. Nothing that the Germans can be compelled to do can remedy the terrific wrongs done in the invaded provinces. Men killed, women and children made to suffer, driven from their lifelong homes, which were destroyed, and the final appalling desolation of a region that was one of the most splendidly developed industrially in the whole world. Great mining plants, picturesque hamlets, and in some cases modern mining villages set in a rich agricultural region with carefully tended gardens and farms, fine roads lined with splendid trees; now all flat and a tangled wilderness of trenches, barbed wire, brick,

and steel. Numerous farms through wide areas have been ruined for many years as the trenching, military mining, and shell craters have buried or blown away the humus, leaving exposed the chalks and marls.

We can only wish our French friends as speedy a recovery from their wounds as possible and so far as possible we should help them to recover in their own way.

FIG. 20.

Camphausen Colliery (former Prussian State mine) in the Saar, showing reinforced concrete head house with 1200 h. p. electric hoist in top.

PRESENT FUEL NEEDS OF FRANCE

Before concluding I will chiefly rehearse the fuel needs of France since the United States is the only country (when we recover from the effects of the suspension of work at our coal mines) that can fill the needs, the shortage of shipping being taken into account. While the loss of output of the destroyed mines, 20,000,000 tons per annum, is a huge amount for France, it is relatively small as compared with the total production of Europe, 614,000,000 tons prior to the war.

Although other mining regions in Europe have not been devastated, their production is suffering most seriously from other causes. In central Europe, owing to military and political conditions, the situation is in a dreadful tangle. In Westphalia there have been numerous strikes and troubles, and the output has been

so reduced that Germany has been unable to supply Switzerland and Holland at its doors.

In England the lessening of hours of employment has reduced the year's production about 60 million tons; the exports, amounting to 77,000,000 tons in 1913, have been but 35 million tons and were obtained by curtailing home consumption.

As Mr. Herbert C. Hoover strikingly pointed out in a coal conference held in Paris on August 4, the rate of Europe's production at that time was only 443,000,000 tons, which is only two-

FIG. 21.

Systematically destroyed Micheville Steel Works in the Briey district, France. The only converter not shipped to Germany

thirds of normal on a prewar basis and this would mean a deficiency of 171,000,000 tons. All of Europe does not need coal at prewar rate at this time, but the fuel needs of France are serious.

Numerous estimates have been made which differ materially from one another according to the assumptions made of consumption and imports available. First, regarding consumption: Will France have the same consumption needs as before the war or, because of the destroyed industries, will the country for a few years require less coal? We will assume, however, that the consumption, not including that of restored Alsace Lorraine, will be the same: Coal, coke, and briquettes, 63,000,000 tons, metric. The next point of uncertainty is, what are the needs of Alsace Lorraine. The industries in these provinces were not destroyed and may

go ahead at a maximum rate. Lieutenant Engel, formerly of the French High Commission, recently detailed in the Saar basin, has estimated these requirements (which are the same as submitted by the French Commission to the recent international trade conference at Atlantic City) at 11,000,000 tons. This makes the total requirements for new France about 74,000,000 tons.

During the war the necessity for fuel caused the coal production in other basins of France and the western part of the Pas-de-Calais basin to be raised from 13,000,000 tons in 1913 to 29,000,000 in 1917. During the past winter this intensive production fell off materially and is now at the rate of less than 20,000,000 but is slowly improving to 22,000,000 tons.

ESTIMATED FRENCH PRODUCTION AND IMPORTS FOR YEAR 1919–1920.

	Tons (metric)
Estimated coal production of French mining, say	22,000,000
Estimated surplus from the Saar fiscal mines and Bavarian mines in the Saar	7,500,000
Lorraine production (extension of Saar basin)	3,500,000
Making the total French production	33,000,000
Necessary coal and coke exports to Italy and Switzerland	2,000,000
Available for French consumption	31,000,000
Total French shortage	43,000,000
To meet this deficit Germany is under obligation to furnish 27,000,000 tons, but is not expected (according to the French Industrial Commission at Atlantic City) to be able to supply this coming year more than*	15,000,000
Belgium can probably supply	5,000,000
The French Commission at Atlantic City expressed the hope that England might be able to supply	9,000,000
The deficit, which will have to be furnished by the United States, if all French needs are met, will approximately be 15.4 million short tons or	14,000,000
Total import needs	43,000,000

* In February 1920, press dispatches indicated that only 600,000 tons per month were being sent by Germany to France. French production for calendar year 1919, 19,538,000 tons, not including Lorraine, and for Lorraine 2,326,000 tons.

PRESENT FUEL SITUATION IN FRANCE.

On account of the difficult fuel situation, the French Parliament has passed a law extending the control of coal distribution for two years, or until the end of 1921. During consideration of the measure, M. Locheur, the Minister for Reconstruction, stated that, although not desiring to be pessimistic, he believed

the crisis would persist until that time. He pointed out that at present the production in the Saar was 50 per cent., that of Westphalia 60 per cent., and of the whole of France not more than 70 per cent. of the previous output, omitting the wrecked mining district. Some of these mines have evidently been in part recovered as M. Locheur stated they were now producing at the rate of 700,000 tons annually.

In September the French output was only 1,600,000 tons, which was less by 600,000 tons than the tonnage raised in certain months during the war, but he anticipated a steady increase in the output through the introduction of foreign labor, agreements having been arranged with Poland and Italy.

Germany, the Minister said, was now sending to France 20,000 tons a day. This would be at the rate of 6 million tons per annum. He put the loss to France alone, through strikes in France, England and Germany at no less than 7 million tons.

The cost of the various coals which France was consuming was as follows (September, 1919):

French	70 francs
German	50 francs
British	150 to 160 francs
American	280 francs

During the first eight months of the present year (1919) French coal and coke imports were as follows:

	Production for year 1919	
	First 8 months Tons	Estimated total year Tons
Imports:		
Coal	10,510,146	15,700,000
Coke	403,286	600,000
Briquettes	942,198	1,400,000
	11,855,630	17,700,000*
Exports:		
French and foreign coal	1,152,585	1,700,000
Coke	45,396	70,000
Briquettes	52,802	80,000
	1,250,783	1,850,000
Total available (imports over exports)	10,604,847	16,000,000

Echo des Mines reports (Jan., 1920) imports for 1919 were 18,601,000 tons.

With a deficiency of 43,000,000 tons, unless imports are speeded up, it is evident that our French friends must go without heat in their homes and forego many things that are regarded as necessaries of modern civilization.

NOTE ON BRANNERITE.*

BY

ROGER C. WELLS, Ph.D.,

U. S. Geological Survey

THE mineral brannerite described in a recent paper in this JOURNAL[1] was carefully tested for helium, as it was expected that a mineral consisting of nearly 50 per cent. of the oxides of uranium, and also containing thorium, should show at least a trace of helium. None was found, however, by the method employed. It was found that some sulphur dioxide was produced by reaction of the mineral and sodium bisulfate, and after removing this with a solution of sodium hydroxide, the remaining gas did not show the characteristic yellow line of the helium spectrum. Shortly after the paper was published the advantages of purifying the evolved gases by means of charcoal and liquid air were brought to the attention of the writer by Dr. R. B. Moore of the Bureau of Mines, and it seemed desirable to repeat the test, using this method. Some highly active charcoal was kindly furnished by Prof. A. B. Lamb of the Fixed Nitrogen Research Laboratory, American University, for the purpose. The clean-up of the gas by this method gave a decisive result indicating the presence of helium, which places the mineral in the list of uranium minerals in which helium has been identified. The test was conducted as follows:

About 5 grams of brannerite was powdered and mixed with previously fused sodium bisulfate in a hard glass tube which was connected by a thick rubber tube to the Töpler pump. Between the hard glass tube and the pump were three stopcocks, and between the latter were sealed the tube containing the charcoal and a spectrum tube, respectively. The system was evacuated until a pressure of about 0.05 mm. was permanently obtained while the charcoal was heated. The spectrum tube and pump were then cut off leaving the stopcock between the charcoal and mineral open while the bisulfate was gently fused. The tube of charcoal was then allowed to stand in liquid air for about half

* Published by permission of the Director, U. S. Geological Survey.

[1] Hess and Wells, this JOURNAL, Feb. 1920, p. 230.

an hour to effect a clean-up of the gas. Finally the gas was admitted to the spectrum tube and a little later the tube was sealed off.

The yellow helium line showed up strongly in the spectrum, and several other lines believed to belong to helium were noted. These observations were made with a spectroscope having an illuminated scale and the wave-lengths were read from a curve based on some familiar flame spectra. The method does not give more than three significant figures. The values found ascribed to helium were 6660, 5880, (yellow line), 5030, 4720, and 4470. Two lines, 6545 and 4870 may represent hydrogen, whereas 6070, 5620, and 5200 are believed to belong to carbon. Among other lines noted but not placed are 5470 and 7000. The spectrum may be examined more carefully later if it should appear desirable but the first object in view was to establish the presence of helium.

At the conclusion of the experiment it was found that approximately half of the mineral taken was decomposed by the short fusion with the bisulfate.

Peat. (*U. S. Geological Survey, Press Bulletin No. 445.*)—The uses of peat are numerous and varied. In the countries of northern Europe it is used for fuel and as the basis for many manufacturing industries. Gas, charcoal, coke, and a number of valuable by-products are produced from it. Owing to the scarcity of raw materials in Europe, peat and peat moss are also employed as substitutes for absorbent cotton in the preparation of surgical dressings, for wood and for cotton and woollen cloth.

In the United States peat is utilized chiefly as fertilizer and fertilizer filler, as stable litter, and as an absorbent for the uncrystallized residues of beet and cane sugar refineries in the manufacture of stock feed.

Peat has long been used in fertilizing the soil, having been either applied as a direct fertilizer or used as a filler for commercial fertilizer. Analyses of the peats of the United States show an average nitrogen content of about 2 per cent., a proportion somewhat higher than that found in some commercial fertilizers. The value of peat in soil fertilization is found in its nitrogen content and in the beneficial mechanical effect it produces upon certain lands. Black, thoroughly decomposed peats are most satisfactory for fertilizer, as such peats are generally heavier and more compact and contain more nitrogen and less fibrous material than the brown types.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

PICNOMETER FOR DETERMINATION OF DENSITY OF MOLASSES.[1]

By W. B. Newkirk.

[ABSTRACT.]

THE determination of the density of molasses has been very inaccurate in previous times. The difficulties which are the cause of these inaccuracies are the high viscosities in the molasses, the dissolved gases which it contains, and the included air which is introduced in mixing.

A picnometer bottle was designed to overcome these difficulties. The volume of the picnometer was controlled as in the picnometer of Johnson and Adams.[2] To this bottle was attached an expansion chamber designed by an anonymous writer[3] and to the expansion chamber was fitted a connection leading to a vacuum. In operation, all ground glass joints are lubricated with the sample to be analyzed. The picnometer and expansion chamber are filled until the expansion chamber is about one-third full. Sufficient vacuum is then applied to liberate all the gases contained in the sample. The apparatus is then sealed from the vacuum source and allowed to remain until all the gas has arisen to the expansion chamber. The volume is then fixed under standard conditions. Results from the use of this picnometer are such that agreements within a few hundredths degrees Brix can be obtained.

It was found that heating causes some unknown decomposition to take place, changing the density of the resulting molasses. The vacuum, when sealed shortly after applying, causes no decomposition and permits a perfect separation of the gases contained in the sample. Several experiments are given, showing the accuracy with which analysis can be made.

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* Communicated by the Director.

[1] Technologic Paper No. 161.

[2] *Jour. of Am. Chem. Soc.*, 34, 566, 1912.

[3] *International Sugar Journal*, 15, p. 489, 1913.

A NEW SPECTRO-PYRHELIOMETER OF THE MEASUREMENTS OF THE COMPONENT RADIATIONS FROM THE SUN AND FROM A QUARTZ MERCURY VAPOR LAMP.[4]

By W. W. Coblentz and H. Kahler.

[ABSTRACT.]

IN this paper a new spectro-pyrheliometer is described, and data are given showing the applicability and the performance of the instrument.

The apparatus consists of a quartz spectrograph and a cylindrical condensing lens, placed upon a simple equatorial mounting. The collimating telescope is pointed directly at the sun, thus avoiding the ultra-violet absorption, which occurs in heliostat mirrors. The radiometric measurements were made by means of a bismuth-silver thermopile of special design.

Data are given on the relative components of the infra-red, visible, and ultra-violet radiation from the sun and from a quartz mercury arc lamp; also data on the ultra-violet component radiation from a gas-filled tungsten lamp, the iron arc and the carbon arc. These data are of interest in dye-fading and other photochemical tests.

In two appendices, methods are given for excluding ultra-violet light from buildings (*e.g.*, balloon hangars) and for protecting projection lantern films from the heat of the lamp.

NOTES ON THE CRITICAL RANGES OF SOME COMMERCIAL NICKEL-STEELS.[5]

By H. Scott.

[ABSTRACT.]

THE transformations in some commercial nickel steels have been studied by means of thermal analysis. The Ac_3 transformation, the temperature of which is of direct practical value in heat-treatment specifications, is also the most difficult to definitely locate. It is found that slow rates of heating give better definition of this point and that the end of the Ac_3 range, as interpreted from the thermal curves, corresponds to the minimum

[4] Scientific Paper No. 378.

[5] Scientific Paper No. 376.

temperature at which all the ferrite is in solution. The effect of rate of temperature change and of nickel content on the critical ranges of the steels, which approximate 0.40 per cent. C content, is shown in curves, and the effect of nickel and carbon on the end of Ac_3 is deduced from the data obtained and that of other observers whose work is discussed. The effect of nickel on the A_1 transformation is to lower Ac_1 by 10.5° C. and Ar_1 by 21.5° C. for each 1 per cent. nickel over the range 0 to 4 per cent. nickel. The eutectoid ratio is also decreased by 0.42 per cent. C. for each 1 per cent. nickel added over the same range.

THE POROSITY AND VOLUME CHANGES OF CLAY FIRE BRICKS AT FURNACE TEMPERATURES.[a]

By George A. Loomis.

[ABSTRACT.]

THIS paper deals with the permanent changes in porosity and volume of clay fire bricks when reburned to temperatures at or above those to which they were originally fired. These were measured for a series of temperatures to determine what relation, if any, might exist between these changes and the deformation of the same bricks under load at furnace temperatures. The possibility of such a relation is suggested by the fact that contraction of clay on heating and decrease in porosity are, to a certain extent, indications of the amount of softening of the mass due to the action of fluxes present and hence indicative of decreased resistance to deformation under pressure or decreased viscosity. Softening point determinations were also made to determine what relations these might bear to the results of the load test.

The results of tests on a large number of clay fire bricks from various parts of the country show that bricks which withstand a load test of 40 pounds per square inch at 1350° C. without marked deformation show no marked changes in porosity or volume up to 1425° C. Bricks which do not withstand the test generally show appreciable contraction or expansion, accompanied by considerable decrease in porosity. Bricks which showed overburning and the development of vesicular structure below 1425° C., by marked expansion or increase in porosity, invariably

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[a] Technologic Paper No. 159.

failed under load. In general, bricks which show a decrease in porosity exceeding 5 per cent. or a volume change exceeding 3 per cent. (amounting to approximately 1 per cent. in linear dimensions) when refired to 1400° C. fail to pass the load test.

No definite relation could be determined between the softening point of a brick and its ability to withstand pressure at high temperature. All bricks softening below cone 28 failed completely in the load test. Some showing quite high softening points also failed, probably due to the use of an inferior bond clay in the mixture or too small an amount of bonding material.

THE EFFECTS OF OILS, GREASES, AND DEGREE OF TANNAGE ON THE PHYSICAL PROPERTIES OF RUSSET HARNESS LEATHER.[7]

By R. C. Bowker and J. B. Churchill.

[ABSTRACT.]

TECHNOLOGIC PAPER No. 160 of the Bureau of Standards contains a description of methods used and presents the results obtained in an investigation to determine the effects of the use of animal and mineral oils, of the amount of stuffing content, and of the degree of tannage on the physical properties of russet harness leather.

Three hides were prepared for the work, one for each test as mentioned above. The method of using double backs was used so that when split and each back was given its special finishing treatment the two leathers compared would come from the same hide. The hide used for studying the effect of the amount of stuffing content on the physical properties consisted of one back which contained an average of 10.7 per cent. and one back which contained an average of 23.35 per cent. To study the effects of the degree of tannage on the physical properties, a hide was split during the tanning process and one back was removed while the other was allowed to remain in the vat a month longer. Both backs were finished in the same manner. The hide used to study the effects of the use of animal and mineral oils on the physical properties consisted of one back stuffed with a mixture

[7] Technologic Paper No. 160.

of 50 per cent. cod oil and 50 per cent. tallow and one back stuffed with a mixture of 50 per cent. Breton mineral oil and 50 per cent. tallow.

The experimental work consisted of a series of tensile strength, percentage stretch, buckle strength, and chemical tests from definite locations on the hide. Results are presented which show the variation in the physical properties over the hide and also the variation of the stuffing content over the hide. The manner in which the physical properties are affected by the treatment of the leather is discussed in detail.

The results of the test indicate that the amount of stuffing content up to a certain limit will serve to increase the strength of the leather after which it does not have this effect and may serve to decrease the strength. It is also shown that the leather given a longer tannage has a lower tensile strength but will have a greater resistance to shearing action. The results of the test to show the effects of the use of animal and mineral oils in the stuffing showed that there were no appreciable effects on the physical properties of the new leather.

THE INTERCRYSTALLINE BRITTLENESS OF LEAD.[8]

By Henry S. Rawdon.

[ABSTRACT.]

SHEET lead sometimes assumes a very brittle granular form during service, due to corrosion. An explanation which has been offered by previous investigators for this change in properties is that it is due to an allotropic transformation, the product resulting from the change being analogous to the well-known "gray tin." Contact with an electrolyte, particularly a weak acid solution of a lead salt, has been claimed to be the agency by which the transformation is brought about.

Metallographic examination of the granular "allotropic" lead shows that each grain has the characteristic properties of the ordinary form of lead. The intercrystalline cohesion of the grains for one another, however, has been so weakened that the material has a granular appearance.

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[8] Scientific Paper No. 377.

The rate at which the intercrystalline brittleness is brought about is proportional to the amount of impurities and to the concentration of acid in the solution in which the lead is placed. Practically all the impurities which are found in lead are lodged in between the grains. The preferential attack by the corroding agent for these impurities and perhaps also for the "amorphous intercrystalline cement" accounts for the brittleness produced. Investigation showed that specimens of exceptionally pure lead (99.993 per cent), when immersed for 24 days in a neutral solution of lead acetate, became appreciably embrittled by the formation of minute intercrystalline fissures. No evidence of the existence of an allotropic form of lead similar to gray tin could be obtained.

Milk Products in America and Europe.—A recent investigation of this field is given in a report by W. DEMPSTER, published in the *New Zealand Journal of Agriculture*, 1920, xx, 97–109. Milk powder is manufactured by the use of heated rolls, or by spraying the previously concentrated milk into a hot chamber. In addition to its other uses in the food industries, skim milk powder or dried skim milk is used with butter in reconstituting milk and cream during seasons of scarcity of fresh milk. In the manufacture of reconstituted cream, the proper amounts of skim milk powder and water are placed in a jacketed vat and are intimately mixed by a propeller which revolves at a high speed. The speed is reduced, the proper amount of butter added, and the temperature of the mixture gradually raised to 145° F., kept constant for twenty to thirty minutes, then lowered to 135° F. The mixture is next put through a homogenizer, and immediately cooled to 45° F. In reconstituting milk, the skim milk powder and water are mixed as just described; the butter, which has been heated to a temperature of 120° F., is now forced through a spray nozzle which lies beneath the surface of the liquid; the finely divided butter fat is uniformly distributed throughout the reconstituted milk. Whole milk powder apparently does not keep well; it seems to require cold storage, *e.g.*, 0 to –8° F., for its preservation. During the war, the production of lactose or sugar of milk increased enormously, since large amounts of that compound were used in the manufacture of smoke-shells. The casein industry of America centres in Philadelphia; this milk protein may be used as the basis of paints, which may be produced in any desired color, withstand water, and retain their color. The shortage of butter in England increased the demand for sweetened condensed milk, which was eaten spread on bread.

J. S. H.

NOTES FROM NELA RESEARCH LABORATORY.*

NOTE ON THE EFFECT OF LACK OF WHITENESS IN THE PAINT AND WINDOW OF THE ULBRICHT SPHERE.

By F. E. Cady.

The theory of the Ulbricht sphere as used in determining the mean spherical candlepower of lamps, calls for an inner surface which is perfectly diffusing and non-selective as to color. These conditions are only approximated in spheres as actually constructed and used. Most white paints change their color with age, and it seems desirable to know how much error an appreciable departure from whiteness will cause when measuring lamps differing in integral color value, as for instance in comparing gas-filled tungsten lamps with vacuum tungsten lamps.

A test of this effect was made using an 80-inch sphere, with a painted inner coating such that its color differed from white as much as a tungsten lamp would change in color if operated at a temperature approximately 200° lower than normal. The window of the sphere had a selective transmission which changed the color of the transmitted light by approximately the same amount. Two different methods were used. One consisted in determining the mean spherical candlepower of some lamps colored so as to have their light match that of a kerosene flame, in terms of normal vacuum tungsten lamps, first with an ordinary photometer and then in the sphere. The other method consisted in getting the ratio of a colored lamp to a normal vacuum lamp, each having been previously measured in terms of a comparison lamp of the same color. Measurements were made on the regular photometer and in the sphere.

The results showed an error due to the selectivity of the paint and the window of 4.5 per cent. by the first method and 5.0 per cent. by the second. Part of the small discrepancy could be accounted for by aging of the paint during the month or so which elapsed between the tests by the two methods. It is concluded that where the color differences are not more than those occurring in the measurement of gas-filled lamps in terms of vacuum lamps, the paint can depart appreciably from whiteness without causing a very large error.

* Communicated by the Director.

NOTE ON SPEED OF FLASHING OF INCANDESCENT SIGNAL LAMPS.

By A. G. Worthing.

A PORTION of a study of the theory of signaling units involving incandescent lamps, which was undertaken in response to a request from the National Research Council and the U. S. Signal Corps for the development of a unit for use in daylight signaling is herein given.

Filament Characteristics Involved.—Various factors involving speed where the telegraphic dot and dash signals are produced by the flashing of an incandescent lamp, are discussed in a broad way in a contrast of tungsten with carbon for filament material. Most important are (1) the change in resistance with change in temperature, (2) the quantity of energy required to heat the filament through a given temperature range, (3) the total emissive power of the filament material, (4) the maximum temperature of a flash, and (5) the efficiency of the radiation in producing vision. For lamps of equal voltage, life and luminous flux, tungsten is favored during the heating portion of a flash by a factor of six or seven.

Observed Speeds and Their Comparison with Expected Values.—A photometric method of studying the performance of lamps on flashing is described and the results obtained with various lamps are presented. These are compared with computed values based on steady current measurements and the supposition that a lamp filament on heating or cooling passes through a succession of steady states. The agreement is quite satisfactory, when there is excepted the case of a filament immersed in hydrogen, where the discrepancy may be ascribed to ionization effects.

Speed Functions.—It is further shown that a simple function involving only steady current measurements of wattage, resistance and temperature in the neighborhood of the maximum temperature of a flash, together with the thermal capacity of the filament, will serve quite accurately in rating various lamps as to their flashing speeds.

Some Fundamental Generalizations.

(1) The time required for a filament to heat to approximately its maximum brightness exceeds greatly the time required in cooling to effectively zero brightness.

(2) The higher the maximum temperature of a flash, the greater is the speed of the flash.
(3) The smaller the filament, the greater is the speed of the flash.
(4) The less the resistance in a circuit external to the flashing lamp, the greater is the speed of the flash.
(5) The speed of flashing for a given filament at a given temperature in various atmospheres—including in vacuo—is the greater, the greater the gas loss.
(6) For lamps of the same open filament construction in various atmospheres, such that they possess the same luminous flux and the same average life at the same fixed voltage, the speed of flashing is the greater, the greater the gas loss.

Ribbon Filaments Versus Wire Filaments.—Due to the quantity of material in a ribbon filament being much less than that in an equivalent wire filament, one should expect in going from a wire filament to a ribbon filament, either a considerable increase in signaling speed, or, without a reduction in speed in gas-filled lamps, a possibility of change in atmosphere to one involving a decreased gas loss (higher efficiency). A contrast of a lamp containing a ribbon filament in argon as proposed by the Nela Research Laboratory in response to the request noted above, with that lamp which was its nearest competitor indicated speeds and efficiencies in favor of the former lamp of the order respectively of 1.6 and 1.25.

The Detection of Finger Prints on Documents.—C. AINSWORTH MITCHELL (*Analyst*, 1920, vol., xlv, 122) has made an extensive study of the methods of rendering finger prints more conspicuous. The extensive adoption of the finger-print method of identifying human beings has led to a stereotyping of the methods and tended to discourage experimental investigation. Mr. Mitchell commends the comparison method introduced by A. S. Osborn, of New York City, by which the resemblances are clearly shown by photographs beneath small squares of ruled glass. A point brought in the present paper is the persistence of the characteristic papillary ridges throughout a long life, in connection with which statement two pictures are shown, being finger prints of Sir William Herschel in 1861 and 1914, respectively. The latter print shows marked weathering of the ridges and some transverse cracks due to age, but the patterns agree in all

essential details. It was Herschel who first introduced the use of finger prints as a safeguard on documents, but the first systematic investigation of the subject and the use of accidental prints as a means of identifying individuals, is due to Dr. Henry Faulds, whose work has been generally overlooked. Faulds paid special attention to the question of "developing" the prints, and suggested the use of certain reagents. The points on which there has been heretofore but little positive information are: (1) The most suitable method for detecting latent prints, such as those on a book. (2) After what period of time is it possible to detect the marks on different qualities of paper. The marks made even by heavy pressure upon the leaves of a book cannot, as a rule, be shown up directly by photography with oblique illumination, and some method of increasing the contrast is required.

The English official method is to dust the surface with a very fine powder, light or dark, according to conditions. A mixture of chalk and the "gray" powder of the pharmacist (a form of mercury) is used for dark surfaces, and finely powdered graphite for light surfaces. Faulds found that a mixture of fine graphite and lampblack gave excellent results. Stokis recommended lycopodium with 10 per cent. of Sudan red. The results with these methods depend much upon the nature of the paper. With highly glazed paper the prints seem to be fairly permanent, and Mitchell has developed them satisfactorily with methylene blue after three years. Highly sized and clayed papers are less liable to retain the impressions.

Since the prints always contain minute amounts of organic matter, especially fatty matters, osmic acid has been suggested as a developer, and has been found efficient in many cases. Mitchell uses a 1 per cent. solution in water, brushed over the print and then exposed to sunlight, by which the ridges become dark, while the furrows are not colored. The method is less effective after long periods. Ink has been used as a developer, but conflicting results have been obtained by different investigators, due probably to the great differences in commercial ink. Mitchell recommends a standard ink made by diluting 2 c.c. of the standard osmic acid reagent for microscopy with an equal volume of water and adding 0.05 gram of pyrogallol. The liquid is ready for use at once, and should be spread over the paper with a soft brush.

Mitchell found that one of the most sensitive reagents is iodine vapor, thus confirming results that had been previously obtained by other investigators. The prints so brought out are, however, fugitive and not easy to photograph. Mercuric iodide vapor was found to be better. The vapor of osmic acid is a very active developer, and is particularly efficient in bringing out the relations, size, and other data concerning the pores, a feature which has been especially applied by Dr. Locard, of Paris.

H. L.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

STUDIES IN NUTRITION. II: THE RÔLE OF CYSTINE IN NUTRITION AS EXEMPLIFIED BY NUTRITION EXPERIMENTS WITH THE PROTEINS OF THE NAVY BEAN, PHASEOLUS VULGARIS.[1]

By Carl O. Johns and A. J. Finks.

[ABSTRACT.]

NUTRITION experiments with the proteins of the navy bean, *Phaseolus vulgaris,* show that they are deficient in cystine. Normal growth is produced if 2 per cent. of cystine is added to cooked phaseolin, the chief protein of the navy bean, or to cooked navy bean meal, if an amount of cystine equivalent to 2 per cent. of its protein content is added, when these furnish the sole source of protein in an otherwise complete diet. Neither uncooked phaseolin nor navy bean meal furnishes adequate protein for growth, even when cystine and the non-protein dietary essential are added. Cystine is thus shown to be an essential amino-acid for normal growth.

THE DETERMINATION OF IODIDE AND BROMIDE IN MINERAL WATERS AND BRINES.[2]

By W. F. Baughman and W. W. Skinner.

[ABSTRACT.]

IODIDE is oxidized to iodate by potassium permanganate in slightly alkaline solution, and the iodate determined iodometrically by adding potassium iodide, acidifying with hydrochloric acid, and titrating the liberated iodine with thiosulphate. For the bromide determination another sample which should not contain more than 0.1 gram of bromine or more than 10 grams of total salts is taken. The iodine is removed from this sample by oxidiz-

* Communicated by the Chief of the Bureau.

[1] Published in *J. Biol. Chem.*, 41 (1920), 379–389.

[2] Published in *J. Ind. Eng. Chem.*, 12 (1920), 358.

ing with ferric sulphate and distilling the liberated iodine with steam. The iodine may be absorbed in a potassium iodide solution and titrated with thiosulphate. The results for iodine obtained by this method are not as accurate as those obtained by the permanganate method (*J. Ind. Eng. Chem.*, 11, 1919, 563). The residue in a distilling flask is emptied into a beaker, heated to boiling, and the iron precipitated with ammonia or sodium hydroxide. The iron hydroxide is removed by filtration and washed with hot water. The filtrate is evaporated to dryness, or nearly so, and the bromine determined in the residue by the chromic acid method (*J. Ind. Eng. Chem.*, 11, 1919, 954). Results of determinations of from 0.04 to 0.08 gram of iodine as iodide and from 0.001 to 0.1 gram of bromine as bromide in the presence of 10 grams of sodium chloride are tabulated.

STUDIES IN NUTRITION. III: THE NUTRITIVE VALUE OF COMMERCIAL CORN GLUTEN MEAL.[3]

By Carl O. Johns, A. J. Finks, and Mabel S. Paul.

[ABSTRACT.]

COMMERCIAL corn gluten meal has been shown to contain adequate proteins for normal growth, but it is lacking in water-soluble vitamines. This deficiency, however, was corrected by the addition of either 3 per cent. of dried brewer's yeast or 18 per cent. of whole gound yellow cornmeal. The addition of cocoanut press-cake to the corn gluten meal furnished the necessary water-soluble vitamines, as well as a very efficient mixture of proteins.

Overseas Touring Exhibitions. (*Electrician*, March 26, 1920.) —For the purpose of bringing British goods to the attention of foreign countries, four traveling exhibitions will be arranged. The first will leave England in June of this year and will return two years later after having visited South Africa, Australia, New Zealand, and Canada. Three other tours will go to the United States, the Far East, and South America. The displays are to be on view for about two weeks in each city where a halt is made.

G. F. S.

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[3] Published in *J. Biol. Chem.*, 41 (1920), 391–399.

NOTES FROM THE U. S. BUREAU OF MINES.*

THE DETERMINATION OF MERCURY.

By C. M. Bouton and L. H. Duschak.

THE volumetric methods for the determination of mercury described in the literature permit the selection of a variation of about 1 mg. of Hg. or within 0.1 per cent. on a 1-gram sample. As much of the world's supply of the metal is obtained from ores carrying less than 1 per cent. mercury, a method that will quickly and accurately determine a variation of less than 1 mg. Hg. is greatly to be desired. Of the numerous methods tested by the investigators of the Berkeley, Calif., stations of the Bureau of Mines in connection with a study of mercury condenser losses, the method of titration with potassium thiocyanate, using ferric sulphate or nitrate as an indicator, proved to be the only one capable of the desired refinement. The titration is vitiated by the presence of any halide; therefore, in bringing the sample into solution, a method must be employed which absolutely excludes all halogen compounds. With slight modification, the method can be applied to the determination of mercury in practically any material, including that containing considerable quantities of organic matter. Details as to the equipment used, analytical procedure, the modifications necessary when organic matter or much sulphur is present, procedure for assaying a filtered precipitate, alternative procedure for refractory samples; and the results of experimental determination of distillation procedure, effects of evolution of gas, possibility of retention of mercury by the charge, trial assay with sulphur and organic matter present, interfering elements, and titration are given in Technical Paper 227 of the Bureau of Mines. With readily provided facilities one operator can make 50 to 60 determinations in an eight-hour day, exclusive of the time required for preparing the sample. Technical Paper 227 also includes a bibliography on analytical methods for the determination of mercury.

* Communicated by the Director.

APPROVED EXPLOSION-PROOF COAL-CUTTING EQUIPMENT.

By L. C. Ilsley and E. J. Gleim.

THE chance of igniting "fire damp," an explosive mixture of methane and air, is the greatest at the working face is a coal mine, where coal-cutting equipment finds its only use. In the United States the development of apparatus for use in gaseous mines has been associated largely with coal-cutting equipment run by electricity. Direct-current motors and alternating-current motors of the slip-ring type when running usually give off electric arcs or flashes that will ignite fire damp. Other motors that have no moving electric contacts may become dangerous through accident, deterioration, or neglect. Auxiliary apparatus, such as fuses, switches, rheostats, and controllers, may arc, flash or become heated to such a degree that fire damp can be ignited. Such equipment is still more dangerous when worn or out of repair.

Danger of causing explosions may arise from lack of protection, weak mechanical construction, incorrect ideas of what constitutes adequate protection, amount and arrangement of internal unoccupied space, the compression of the gas with the machine, and the percentage of gas and the amount and distribution of coal dust. The chief problem of the manufacturer of apparatus suitable for fire damp atmospheres is that of extracting heat from possible explosive flames and cooling them below the ignition temperature of methane as they pass through the openings. Gas light apparatus is not practicable for mine service, because of the difficulty of inspection and making renewals. Totally enclosed apparatus has the advantages of simplicity of design, slight deterioration, and freedom for excessive dust troubles. Partly enclosed apparatus is provided with openings in which are placed heat-abstracting devices. These afford a certain amount of ventilation. The design and maintenance of safe heat-abstracting devices is the chief problem of apparatus of this class. Schedule 2A of the Bureau of Mines, stating the procedure for establishing a test of permissible explosion-proof motors, was issued November 2, 1915, and the investigation made under its regulations are described in Bulletin 78 of the Bureau of Mines. These include tests made on explosion-proof motors, coal-cutting equipment and locomotives.

MINING AND PREPARING DOMESTIC GRAPHITE FOR CRUCIBLE USE.

By Geo. D. Dub and F. G. Moses.

Before 1915 nearly all the graphite used in crucible manufacture in the United States was imported, the small domestic output being used for lubricants, paints, foundry facings, and other purposes, but the combination of large demand for crucibles and the short life of crucibles made from other than the Klingenberg clay, no longer attainable, lead to its use in greatly increased quantities. The War Industries Board finally ruled that 20 per cent. domestic flake graphite should be used in crucible mixture during 1918 and 25 per cent. during 1919. Alabama, New York, Pennsylvania and Texas were the principal producing states, there being thirty-nine plants in three counties of Alabama. New York, which for many years had been the principal source of domestic production, had only three mines in operation in 1918, having yielded first place to Alabama. In Pennsylvania five plants were in operation in Chester County. While in Texas, three properties were active, in 1918, in the central region between Llano and Burnet. Details as to these operations, methods of concentration of the ores, the preparation of domestic graphite for crucible use, are given in Bulletin 112 of the Bureau of Mines. The method of rapid analysis of graphite used by the Bureau of Mines is also described. There are four methods of concentrating graphite ores, water "skin flotation," the pneumatic process, the log-washer process, and oil-froth flotation. The product of the first concentration is a comparatively low-grade concentrate. The second step, finishing, as it is called, is much more difficult to carry out, and is the one that demands the greatest amount of investigation and improvement. Much experimental work on the preparation of Alabama graphite was carried on at the Salt Lake City station of the Bureau of Mines by F. G. Moses. The whole success of a finishing process depends on the removal of a large percentage of coarse hard impurities that tend to cause excessive destruction of valuable flake in the buhr-mill grinding. Details as to the investigations and the processes recommended are given in the bulletin of the Bureau of Mines already referred to.

Potash Deposits in Spain. (*U. S. Geological Survey Press Bulletin, No. 443,* April, 1920.)—Potash deposits were discovered a few years ago in the Province of Barcelona, Spain, near the villages of Suria and Cardona. They consist of irregular beds of carnallite and sylvinite interbedded with rock salt. Explorations to a depth of several hundred feet show that in the Suria district potash beds occupy an area of not less than 75 acres and occur at depths from 125 to 200 feet. The average combined thickness of the carnallite beds is estimated to be about 56 feet, and of the sylvinite about 13 feet. The Cardona upper beds are interbedded with gypsum and clay, but the lower beds contain nearly pure white salt, which is that principally mined. After the discovery of potash at Suria, these Cardona beds were searched for potash, and nearly pure sylvite was found. Estimates for the area prospected place the quantity of carnallite at 2,550,000 tons and of sylvinite at 1,150,000 tons.

Aluminum honeycombs are frames in which thin strips of aluminum are ingeniously worked into the shape of worker-cells. The surface of these cells is slightly brushed with beeswax; the bees build on these edges until the combs are of such depth as the spacing of the frames will permit. The metal combs are claimed to enable a greater production of honey, since time is saved in building the wax, and they extract cleaner and do not break. In experiments on aluminum honeycombs, conducted by G. V. WESTBROOKE (*New Zealand Journal of Agriculture,* 1920, xx, 118–119), light honey was readily extracted from the combs. In combs with thick honey, when extra speed was applied to the extractor, most of the honey was obtained; only a few cells retained a small amount; the combs showed no signs of breaking in spite of the high speed of the extractor.

J. S. H.

The Output in Sawing Metals by Hand. CH. FREMONT. (*Comptes Rendus,* March 22, 1920.)—It takes less time to saw a rectangular bar of steel when the saw is moved parallel to the shorter side of the rectangle than when it moves parallel to the longer side. Further, the output grows less as the length of the saw cut lengthens. The same workman who sawed the steel of a rail at the rate of 3.4 sq. cm. per minute when the cut was 1 cm. long, dropped to 1.25 sq. cm. when the cut was 10 cm. in length. The output per minute decreased regularly by .25 sq. cm. for each increase of 1 cm. in the length of the cut.

When the end of the saw away from the workman was supported not by his hand but by a simple pendular device it was found that the time required for sawing was shortened, a thinner blade could be used, and a better surface resulted.

G. F. S.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting held Wednesday, May 19, 1920.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, MAY 19, 1920.

PRESIDENT DR. WALTON CLARK *in the Chair.*

By consent, the reading of the minutes of the previous meeting was dispensed with.

Additions to membership: 6.

The President announced that the business of the meeting would be the annual presentation of The Franklin Medal, the Institute's highest award in recognition of distinguished and scientific achievements, and called upon Dr. Harry F. Keller, who gave an account of the work of the Honorable Sir Charles A. Parsons, K.C.B., C.B., M.A., LL.D., D.Sc., F.R.S., of Newcastle-on-Tyne, England, recently recommended by the Institute's Committee on Science and the Arts for The Franklin Medal in recognition of "His epoch-making success in the development and construction of the steam turbine, which has revolutionized the art of steam engineering, particularly in regard to the propulsion of mercantile and naval vessels and the driving of electrical generators."

Sir Auckland Geddes, British Ambassador, was then presented to the President, and received from him The Franklin Medal awarded to the Honorable Sir Charles A. Parsons. His Excellency conveyed the thanks of his Government for the honor conferred upon his distinguished countryman, and said that such gracious acts went far to insure the continuance of the happy relations which have so long obtained between Great Britain and America.

Doctor Keller was again recognized, and described the work of Professor Svante August Arrhenius, Ph.D., M.D., D.Sc., LL.D., of the Nobel Institute, Stockholm, Sweden, who had also been awarded The Franklin Medal, in recognition of "His notable contributions to the theory of physical science, which have found unprecedentedly extended and fruitful application in the experimental study of chemical, physical, biological and cosmic phenomena, as well as in industrial chemistry," and introduced Mr. Joen de Lagerberg, Secretary of the Swedish Legation at Washington, who accepted The Franklin Medal and extended the appreciative thanks of His Swedish Majesty's Government for the honor done Professor Arrhenius.

The paper, "Some Reminiscences of Early Days of Turbine Development," by Sir Charles A. Parsons, was read by Mr. Charles Day, Vice-President of the Institute.

The paper, "The Problem of the World's Supply of Energy," by Professor Svante August Arrhenius, was read by Dr. Allerton S. Cushman, Director of The Institute of Industrial Research, Washington, D. C.

Adjourned.

R. B. OWENS,
Secretary.

(A full account of the meeting will appear in the next issue of the JOURNAL.)

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, May 5, 1920.*)

HALL OF THE INSTITUTE,
PHILADELPHIA, May 5, 1920.

MR. CHARLES PENROSE *in the Chair.*

The following report was presented for final action:
No. 2747: Principles of Concealing Coloration. Advisory.
The following report was presented for first reading:
No. 2748: Bullard Mult-Au-Matic.

R. B. OWENS,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(*Stated Meeting, Board of Managers, May 12, 1920.*)

RESIDENT.

MR. CHARLES PHILIP BOWER, Civil Engineer, 403 Westview Avenue, Germantown, Philadelphia, Pennsylvania.

MR. WARREN MATHEWS FOOTE, President, Foote Mineral Company, and for mail, Swarthmore, Pennsylvania.

MR. FRANK H. STEWART, Textile Manufacturer, in care of Krout & Fite Manufacturing Company, 1950 East Allegheny Avenue, Philadelphia, Pennsylvania.

NON-RESIDENT.

MR. ISAAC W. BYERS, Retired, Iron River, Michigan.

ASSOCIATE.

MR. JULIUS COHEN, Chemist, 5605 Wyalusing Avenue, Philadelphia, Pennsylvania.

MR. FRANCIS W. HARTZELL, Carburetted Water Gas Manufacturer, 728 Robbins Avenue, Philadelphia, Pennsylvania.

CHANGES OF ADDRESS.

DR. LUCIUS P. BROWN, Franklin, Tennessee.

MR. R. W. DAVIDS, Merion Station, Pennsylvania.

MR. W. W. DAVIS, in care of Semet-Solvay Company, Syracuse, New York.

MR. EDWIN ELLIOTT, 403 West Price Street, Germantown, Philadelphia, Pennsylvania.

MR. ARMIN ELMENDORF, Haskelite Manufacturing Corporation, 819 Chamber of Commerce Building, Chicago, Illinois.

MR. J. G. FELTON, Manager, Wisconsin-Minnesota Light and Power Company, La Crosse, Wisconsin.

MR. EDWIN FRANK, 5216 Laurens Street, Philadelphia, Pennsylvania.

MR. FRANCIS H. GILPIN, 22 Edgemont Avenue, Summit, New Jersey.

DR. C. J. HEXAMER, The Bartram, 33rd and Chestnut Streets, Philadelphia, Pennsylvania.

MR. FRANKLIN S. HORN, 1515 Arch Street, Philadelphia, Pennsylvania.

MR. H. J. KALTENTHALER, 6457 Woodbine Avenue, Overbrook, Philadelphia, Pennsylvania.

DR. E. F. KINGSBURY, Western Electric Company, 463 West Street, New York, New York.

CAPTAIN CHESTER LICHTENBERG, 137 Park Avenue, Schenectady, New York.

MR. R. A. MARRIOTT, 431 East 10th Street, Long Beach, California.

MR. CHARLES E. RICHARDSON, Charles E. Richardson & Company, Engineers, 25 East 41st Street, New York, New York.

MR. H. R. STANFORD, Naval Operating Base, Hampton Roads, Norfolk, Virginia.

MR. DAVID H. WILSON, JR., 253 36th Street, Brooklyn, New York.

NECROLOGY.

John A. Brashear. By the death of John A. Brashear, astro-physics has lost one of its most skilful and earnest workers. Beginning his active life as a maker of optical instruments, he secured before the termination of it an international reputation in its practical and theoretical fields. In early life, too poor to buy a telescope to gratify his desire to study the skies, he made the lenses for one, working at this task at night while he earned his living in a mill by day. It is not without interest that we read that his wife assisted him to the extent of her ability in his scientific labors, and by her inspiration and encouragement he was helped in his triumph over failures and occasional despair.

Later, when he took up, as a business, the manufacturing of lenses, he found that efficiency in that field would not spell financial success, for those who are interested in astro-physics are few and far between, and the difficulties and risks of the making of large, high-grade optical instruments are numerous.

When the question arose of establishing a standard of length more durable than the standards deposited respectively in London (the yard) and Paris (the metre), Michelson suggested that the wave-length of light might serve as datum, unchangeable and indestructible. The construction of the instrument for this purpose was committed to Brashear, and it was successfully carried out, an extremely accurate and delicate apparatus being produced.

Among his greatest triumphs in telescope construction are the 72-inch parabolic mirror for the Dominion Observatory, Victoria, Canada; 37-inch parabolic mirrors for the Lick Observatory and University of Michigan; a 16-inch photographic doublet for the Koenigsthal Observatory, Heidelburg, Germany. He has designed and constructed many spectroscopes for astronomical purposes, and made the speculum plates for Professor Rowland's diffraction gratings.

He was honored by degrees from institutions of learning of highest standing, among which was the degree of Sc.D. from Princeton University. He was member of many learned societies and was elected an honorary member of The Franklin Institute on April 4, 1919.

Doctor Brashear's opportunities were extended by the attention that he attracted from Langley, through whose efforts he was enabled to move to Allegheny, where he set up a shop for lens grinding, which was the beginning of the firm afterwards of world-wide reputation.

It is interesting to note that he was not neglectful of his less fortunate fellow men and women, for some years before his death he founded the Brashear Settlement Association, which has its headquarters in the house in which he spent his earlier years.

He died on April 8, 1920, having reached within a few months of the Psalmist's utmost span of life. His wife died a few years before him, and their joint tomb bears the beautiful epitaph written by Brashear: "We have loved the stars too fondly to be fearful of the night."

H. L.

LIBRARY NOTES.

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Worthington Pump and Machinery Corporation, Catalogue of Condensing Apparatus. New York, N. Y., 1920. (From the Corporation.)

BOOK NOTICES.

AIRPLANE PHOTOGRAPHY. By Herbert E. Ives, Major, Aviation Section, Signal Officers' Reserve Corps, U. S. A. 413 pages, contents and index. 208 illustrations, 8vo. J. B. Lippincott Company, Philadelphia and London, 1920. $4.00 net.

Taking up this book for examination, on May 6, 1920, the reviewer is reminded that it is "Langley Day," the twenty-fourth anniversary of the first flight ever made by a heavier than air machine under its own power developed in the machine itself. It was on May 6, 1896, that Samuel Pierpont Langley succeeded in operating his "aerodrome" on the Potomac River, near Quantico, in a sustained flight for about 3300 feet, at a height of about 75 feet and a speed of about 20 miles per hour. These figures seem trifling now when we are familiar with transoceanic and transcontinental journeys, soaring in the empyrean above the tops of the highest mountains, and with speeds double that of the average express train, but the difficulties against which Langley strove were enormous, for he had not only to develop the mathematics and mechanics of flight, but to encounter a vast amount of antagonism both from the ignorant and the learned. Most persons in control in the government of the United States regarded Langley as a dreamer and sneered at his efforts. This is what might have been expected, for the mass of the community has no respect for or interest in pure science, but the more bitter experience was the disapproval of learned men. Lord Kelvin and Doctor Newcomb said that the flight of a heavier than air machine as large as an ordinary bird was impossible, yet at the time these statements were made the mathematical and practical demonstrations of the possibility of such flight were available to all.

The book before us does not deal with either the history of the development of the flying machine or with its physics or construction. It is devoted to that remarkable and valuable development, perhaps the most important application, the photography of the district covered in the flight. It needs no words to inform us of the great use that the airplane has been in war, and that one of the most important of its uses was

the securing of photographs of the enemy's works and movements. Photographs of this type are too familiar to need description. Doctor Ives was exceptionally well qualified to take a large part in the operation of the photographic department of the Signal Corps, and the present work, which summarizes in plain language the methods, difficulties and results of the work, will be a welcome addition to the literature of the subject. He has not overlooked the application of airplanes to the arts of peace, and devotes a chapter to the probable future developments in apparatus and methods, to the technical and pictorial uses of the machine and to its use in exploration and map making. It seems that the former application, namely, exploration, will be of special value, since it will enable correct geographical and geophysical data to be obtained in parts of the world in which conditions of travel, hostility of inhabitants or the dangers from disease make the ordinary methods of exploration difficult or practically impossible.

The author is to be commended for the excellence of the text and convenience of arrangement, and the printer for the liberal use of illustrations of a very high class.

HENRY LEFFMANN.

LABORATORY MANUAL OF ELEMENTARY COLLOID CHEMISTRY. By Emil Hatschek. 131 pages, contents, indexes and 20 illustrations, small 8vo. Philadelphia, P. Blakiston's Son & Company. $2.00, net.

The author of this work is so well and favorably known in connection with the subject of the colloidal state, that one may expect that it will be a valuable addition to the literature of the subject, and examination does not disappoint. In a compact form a large number of procedures for the preparation of the several classes of colloidal conditions are described, also many illustrative experiments on the nature and properties of these conditions. The data are based throughout, the author informs us, on personal experience, not only in carrying out the processes, but in teaching them, the latter being, indeed, one of the best methods of studying a subject. It is related in a recently published work, that Van t'Hoff once said, in public, that he did not understand Avogadro's postulate until it became his duty to teach it. The book will be a great advantage to the older class of teachers to whom the difficulties of illustrating and explaining this now important subject have been a serious matter.

In connection with the general descriptions of apparatus and methods, considerable attention is given to the standards of purity of the reagents, and the resisting power of the containers, among which we note the caution that test-tubes which in a brief period cause distilled water placed in them to turn phenolphthalin pink are not uncommon among laboratory supplies, and should not be used in this work. Caution in regard to thorough cleaning is also given.

The work is a valuable addition to the literature of a growing and important department of physical chemistry.

HENRY LEFFMANN.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS. Report No. 43. Synopsis of Aeronautic Radiator Investigations for the Years 1917 and 1918. Preprint from the Fifth Annual Report. 8 pages, illustrations, quarto. Washington, Government Printing Office, 1920.

The report outlines the factors to be considered in studying radiators, and discusses briefly characteristics of core structure and conditions under which the radiator is used. Properties that indicate the performance of the radiator are defined, and their relations to each other are pointed out. Performance curves for four representative types show how the properties vary with speed of flight. Some of the more important conclusions of the investigations are pointed out, including curves showing the effect of rate of water flow on heat transfer, and a method for estimating the performance of a radiator at altitudes.

Report No. 69. A Study of Airplane Ranges and Useful Loads. Preprint from the Fifth Annual Report. 29 pages, illustrations, quarto. Washington, Government Printing Office, 1920.

This report considers the question of possible ranges and useful loads for airplanes from two points of view. A sample calculation is made, using a step-by-step method, and a theoretical solution is carried through and the two results compared. It is shown that the two methods check each other in a very satisfactory way, which is fortunate, as the theoretical formulæ may be used with confidence, and their numerical application is a very simple matter.

It is quite evident that the factors upon which large range depends are the lift over drift ratio for the complete machine, the ratio of weight empty to weight fully loaded, the fuel consumption per horsepower hour of the motor and the efficiency of the propeller. The qualities of an airplane are completely characterized by these factors. The theoretical solution gives explicitly the way these factors contribute to its range and load carrying properties.

The question of range with useful load is considered, including a flight to an objective, delivery of load and return without refueling, this problem being of interest with respect to bombing. It is completely solved, and a very practical and expeditious method is derived for all possible cases. Among other results are equations giving-time to attain a given distance-time required to use up a given weight of fuel and distance corresponding to a given weight of fuel. The effects of climb at start and glide at end of flight are shown to be practically negligible.

Comparisons of high speed flight and flight with minimum power are made with greatest range or economical flight, especially with regard to load carrying range and time. A special method for determining the effect of the wind from a single curve for all wind speeds, either with or against the direction of flight, is derived and applied, and the effect of wind on angles of incidence for most economical flight is determined. Most of the formulæ are applicable not only to range flights at most economical angles, but also flight at any angle of incidence.

Report No. 71. Slip-stream Corrections in Performance Computa-

tion. Preprint from the Fifth Annual Report. 12 pages, illustrations, quarto. Washington, Government Printing Office, 1920.

This publication is concerned with the variation of slip-stream velocity with rate of advance of a propeller, and treats the subject both from the experimental and the analytical standpoint. The experimental portion is based on Eiffel's work. The relative increase in slip-stream velocity is much less rapid than that in air-speed, and the slip-stream correction, therefore, falls off as the air-speed increases. A method, based on the momentum theory of propulsion, is given for determining the slip-stream correction for any given propeller under any conditions. The curve of slip-stream velocities thus determined by theory checks extremely well (within 2 per cent.) with the experimental curve for the one propeller for which data are available.

Report No. 75. The Aerodynamic Properties of Thick Aerofoils Suitable for Internal Bracing. Preprint from the Fifth Annual Report. 26 pages, illustrations, quarto. Washington, Government Printing Office, 1920.

This report deals with the results of a series of tests conducted at the Massachusetts Institute of Technology wind tunnel, with a view to developing aerofoil sections thick enough to permit of internal bracing and the use of cantilever wings without any external bracing of the airplane wing truss. The sections tested were based on the Durand 13, and were varied in section form, in thickness along the span, and in chord along the span. Tapering both in thickness and in chord was found to be highly beneficial to efficiency, and some of the wings developed gave L/D ratios practically as high at angles corresponding to very high speeds of flight as the best of the wing sections for normal type, together with very much higher maximum lift coefficients.

Report No. 76. Analysis of Fuselage Stresses. Preprint from the Fifth Annual Report. 15 pages, illustrations, quarto. Washington, Government Printing Office, 1920.

Prepared by the staff of the Committee at Langley Field, this report is concerned chiefly with the assumptions to be made as to the loading on fuselages. A typical "stick-and-wire" fuselage is analyzed for four different sets of assumptions as to landing loads and for three different conditions in flying. In treating flying conditions, all the inertia loads are included, and a single diagram is drawn including all the members from nose to tail. The inertia loads due to angular accelerations are shown to be very important and to decrease the stresses in the rear of the fuselage by more than 50 per cent. in some instances.

The discussion of stress analysis by graphical methods is, of course, applicable only to "stick-and-wire" fuselages, but the treatment of inertia, damping, and tail loads is equally useful for veneer and monocoque designs. As a result of this investigation of loads certain recommendations are made as to the distribution of loads in sand-load testing of fuselages.

Copies of the above reports may be obtained from the Committee.

R.

PUBLICATIONS RECEIVED.

U. S. Bureau of Mines: Bulletin 78, Approved Explosion-proof Coal-cutting Equipment, by L. C. Ilsley and E. J. Gleim. 53 pages, illustrations, plates, 8vo. Washington, Government Printing Office, 1920. Bulletin 183, Abstract of Current Decisions on Mines and Mining Reported May–August, 1919, by J. W. Thompson. 167 pages, 8vo. Washington, Government Printing Office, 1920.

U. S. Coast and Geodetic Survey: Terrestrial Magnetism. Alaska magnetic tables and magnetic charts for 1920, by Daniel L. Hazard, Assistant Chief, Division of Terrestrial Magnetism. Special Publication No. 63. 31 pages, maps, 8vo. Washington, Government Printing Office, 1920. Price, twenty cents.

University of Illinois Bulletin: The Relation Between the Elastic Strengths of Steels in Tension, Compression and Shear, by Fred B. Seely and William J. Putnam. Bulletin No. 115, Engineering Experiment Station. 49 pages, illustrations, 8vo. Urbana, Engineering Experiment Station, 1919. Price, twenty cents.

Engineering Experiment Station, University of Washington: Engineering Experiment Station Series Bulletin No. 5. Electrometallurgical and Electrochemical Industry in the State of Washington, by Charles Denham Grier. 43 pages, 8vo. Seattle, University, 1920.

Panchromatism: Second edition, revised and enlarged. 32 pages, illustrations, plates, colored frontispiece, 8vo. London, Ilford, Limited. No date.

The Fabric of Cosmic Energy: The suggestion of a substitute for the space-filling ether, by John Leuthold. 12 pages, 24mo. Breckenridge, Colorado. Reprinted from the Summit County Star, 1920.

Potash. (*U. S. Geological Survey, Press Bulletin No. 445.*)—Silicate rocks, which are widely distributed over the United States, contain potash in an insoluble combination and in a form which is not available for industrial use, but they are gradually decomposed on exposure to the weather. The potash, thus rendered soluble, is dissolved by rain or ground water, and it finally reaches the ocean or inclosed drainage basins through streams or is absorbed from percolating water by clays.

River waters of North America contain an average of 281 parts per million dissolved salts, of which an average of 1.77 per cent. is potassium. They carry annually to the ocean 8,339,800 metric tons of potassium, and the river waters of the world carry 57,892,000 metric tons. The annual precipitation of potassium in insoluble form in the ocean is 50,320,000 metric tons, leaving an annual gain of potassium by the ocean of 7,662,000 metric tons. The total potassium content of the ocean is 510,800,000,000,000 metric tons. Ocean water contains 3.30 per cent. of salts, of which 1.11 per cent. is potassium, corresponding to 1.38 per cent. of potash (K_2O).

CURRENT TOPICS.

New Methods for Cheap Fuels. (*American Chemical Society News Service.*)—Costs of heat and power are likely to be much reduced by the use of the new colloidal fuel described at the recent spring meeting of the American Chemical Society, held in St. Louis. A combination of finely divided coal dust and of waste from stills, which is held together in emulsion form by soap-like substances, this fuel will undoubtedly have an important effect upon industry.

In view of the many inquiries made from all parts of the country, the paper describing this new factor in industrial economy is produced in full in the current number of the *Journal of Industrial and Engineering Chemistry*. Its author, Mr. Jerome Alexander, of New York City, gives due credit to all concerned in the development of this latest application of colloidal chemistry—that branch of science which relates to substances in a state of fine suspension, such as may be found in emulsions and gelatins.

"What promises to be one of the most far-reaching advances made under the stress of the recent war," writes Mr. Alexander, "when necessity literally was the mother of invention, is the discovery that by means of a suitable fixation, or peptizing agent, and suitable treatment, very large percentages of cheap tars and finely powdered coal waste may be dispersed in fuel oil with a sufficient degree of permanence to enable the mixture to be stored, piped, atomized and burned practically like fuel oil itself.

"Since it will at one stroke relieve the drain on the earth's rapidly diminishing stores of petroleum, as well as lead to the efficient utilization of all kinds of coal waste, such as culm, screenings and dust, inferior fuels such as peat and lignite, and even cellulose waste, such as slabs and sawdust, this new composite fuel may be hailed as a powerful factor in the conservation of our natural resources and as a lasting benefit to mankind.

"Realizing the vital importance of the Allies' oil supply in the conduct of naval, military, and manufacturing operations, the German submarines bent every effort to destroy tankers. Marshal Foch is said to have cabled America: 'If you don't keep up your petroleum service, we shall lose the war.' While the Allies' navies were dealing with this peril in a most decisive fashion, Lindon W. Bates, of New York, head of the Engineering Committee of the Submarine Defense Association, with the assistance in laboratory matters of Dr. S. E. Shepperd and other chemists of the Eastman Kodak Company, courteously opened to him, developed a colloidal fuel which, by practically doubling

the usefulness of every oil cargo, would of itself have materially assisted the defeat of the efforts of the Hun.

"Coal or other combustible solid," says Doctor Alexander in explanation, "is prepared for dispersion by being pulverized so that about 95 per cent. passes through a sieve which has one hundred meshes to the square inch. This means, of course, that by far the greatest weight is in particles hundreds and hundreds of times larger than colloidal dimensions."

Doctor Alexander also described how this new development in chemistry was employed by war vessels in creating colloidal clouds for smoke screens in order to outwit the pursuing submarines.

Neon Lamps in Stroboscopic Work. (*Proc. Cambridge Philos. Soc.*, 1920, vol. xix, 300.)—F. W. ASHTON describes the construction and operation of a lamp containing neon under reduced pressure, which is especially satisfactory for illumination of a moving object by flashes of very short duration. The rate of interruption can be controlled by an electrically driven tuning-fork, so that the efficiency of any given method will depend on the shortness and brightness of the flashes, and the character of the light in its action on the eye. Experiments with naked Leyden-jar sparks having been found unsatisfactory, attention was turned to neon, and a form of lamp was designed and filled with the gas. This turned out to be a great success. Ashton describes in detail the form of lamp finally adopted, which cannot be made clear without the illustration. Apart from accident, the lamp is serviceable until the pressure of the gas becomes too low for the spark to light it adequately. The life appears to consist of two distinct periods. The first is during the time when the chemically active impurities derived from the electrodes and walls of the tube are being slowly and completely eliminated (as far as spectroscopic tests go), and the second period is one in which the sputtering of the cathode occurs, and the neon itself begins to disappear. During the first period the luminosity steadily increases, remaining almost constant during the second period until rapid decrease occurs. So far the best results have been obtained from a batch of lamps filled at 10 mm. pressure, some with pure neon, some with a mixture of neon and 10 per cent. of helium. One of the latter type had a working life of over 3000 hours, the helium disappearing from the spectrum after the first few hundred hours.

Ordinary gases give but feeble illumination, carbon monoxide being about the best. Helium gives a bright discharge, but not nearly so satisfactory for visual work as neon. The brilliant orange-red glow of neon is composed almost entirely of lines in the region 5700–6700 A.U., and is in such striking contrast to sunlight that stroboscopic observations can be made in daylight, if necessary. Ashton, referring to the growing technical importance of neon, advises that engineers of liquid air production

should consider the erection of fractionating plants for obtaining the gas from the air which contains 0.00123 per cent. by volume. Such a plant now exists in Paris, operated by George Claude, to whom the author of the paper was indebted for the neon used.

H. L.

Bureau of Mines' New Director.—The nomination of Dr. Frederick G. Cottrell as Director of the Bureau of Mines, and the recent award to him, by the Chicago section of the American Chemical Society, of the Willard Gibbs Medal, calls special attention to the great service that Doctor Cottrell has rendered to chemical industry by the development of the method of removing suspended matters from gaseous products of many mining and manufacturing operations. Doctor Cottrell, now forty-three years of age, graduated at the University of California in 1893, studied abroad, and subsequently was connected with his *alma mater* in the teaching of physical chemistry. He was consulted in regard to the problem of removing fumes from the discharges of a sulphuric acid plant, at a copper smelter. Much trouble had arisen about the matter, the state authorities threatening to close the works unless the nuisance was abated. The plan he adopted, which was successful, was to place at the bottom of the flues chains carrying powerful electric currents, which caused the particles to fall, clarifying the gases. The process was extended to many other industries and will be very useful in decreasing the offensive character of many plants. Doctor Cottrell took out patents, but arranged that all profit therefrom should go to a non-dividend paying company, "The Research Corporation," devoted to the encouragement of research.

H. L.

The Albedo of the Contents of the Air. L. WEBER. (*Ann. d. Phys.*, vol. li, 1916.)—When a beam of light traverses a darkened room, a considerable quantity of light is diffusely reflected from the motes in the path of the light. In the open air motes are present and the illumination is stronger. Hence the diffused light must be produced even if it is not so obtrusive.

For the measurement of the diffuse light a type of photometer was used in which the observer looked through a layer of air toward a cavity from which no light was reflected back into the instrument. Light from a milk-glass globe, illuminated by daylight, was reflected so that it could be directly compared with the light reflected from the layer of air. The experiment led to the determination of the depth of air which would furnish an intensity of light equal to daylight. On a very clear day this distance was found to be about 50 km. and on a cloudy day 3.3 km. Absorption is, however, not taken into account in the calculations.

G. F. S.

United States Power Program. (*U. S. Geological Survey Press Bulletin,* No. 435, December, 1919.)—Under the war demand for fuel conservation the hydraulic engineers of the United States Geological Survey, Department of the Interior, served the Fuel Administration in a field study of power problems.

A power survey of the United States was begun, and at the end of the war Secretary of the Interior Lane asked of Congress two appropriations, one of $50,000, for continuing this power survey over the whole United States, and the other of $200,000, for an extensive survey of the industrial zone of the East, where power requirements are most congested. At present in the central power plants of the country water power carries only about 40 per cent. of the load, while the total fuel requirement for steam-generated power, including that of the railroads, is not less than 800,000 tons daily. A power program that calls for the immediate and full development of every available and feasible water power, moreover, means saving both in coal and in man power, and with this purpose of securing the double conservation, the investigation has been proposed. The first step is to get the facts for the country as a whole and particularly for the North Atlantic industrial district.

This "super-power" project, which engineers agree seems wholly practicable but which can be regarded as now only in the vision stage, is to pool the power supply for the whole industrial area between Boston and Washington, in which is concentrated one-fourth of the power-generating capacity of the country. Such a unified power system would tie together properly located steam-electric and hydroelectric plants—old plants that are efficient as well as new plants—in a great power main from which would flow the energy to serve a score of railroads, hundreds of public-service companies, thousands of mills and factories, and millions of homes.

The subject is necessarily one for interstate investigation and is linked with the national problem of providing adequate transportation facilities. Electrification of our railroads would effect fuel economies of more than 50 per cent. in coal consumed, not to mention the greater efficiency of electric traction through increasing road capacity. Equally important, moreover, is the relation of cheaper power to American industry. As stated by Secretary Lane in a letter transmitting the estimate for this appropriation: "Only by increased economy in the production and distribution of power will it be possible for our manufacturers to decrease their production expenses and compete successfully in the world's markets, maintaining at the same time the American standard of wages and living."

Some Inorganic Poisons were discussed by ALICE HAMILTON, of the U. S. Bureau of Labor Statistics, in a lecture delivered at the Harvard Medical School, and published in the *Chemical Trade Journal and Chemical Engineer,* 1919, lxv, 365–367. The lecture deals primarily with industrial poisoning. Arsenical poisoning may occur in the manufacture of certain insecticides, such as lead arsenate and Paris green. The workmen are best protected by plugging the ears and nostrils lightly with cotton, smearing the face with a bland ointment, wearing clean work clothes each day, and use of a full shower bath at the end of each day's work. Poisoning by arsine (hydrogen arsenide) may take place when moisture acts on ferrosilicon which contains 40 to 60 per cent. silicon; the ferrosilicon contains as an impurity calcium arsenide which reacts with water under these conditions to liberate arsine. Antimonial poisoning has not been reported among workers in the printing trade; its occurrence among rubber workers is uncertain, though possible. Golden and crimson sulphides of antimony—really mixtures of its pentasulphide, trisulphide and oxysulphide—are used in large amounts in the manufacture of rubber; human gastric juice dissolves approximately 8 per cent. of the antimony present in the crimson sulphide, and about 3 per cent. of the antimony present in the golden sulphide. Mercurial poisoning may attack mercury thermometer makers, and workmen who manipulate mercury vacuum pumps in the manufacture of incandescent lamps and similar apparatus. Since mercuric nitrate is used in the preparation of felt for hats, mercurial poisoning may occur among workers in that industry. Use of carbon disulphide in the rubber industry of continental Europe has caused many cases of poisoning. In the United States, poisoning by carbon disulphide vapors has been observed among workers in the manufacture of artificial silk from cellulose, carbon disulphide, and caustic soda. While poisoning by phosphorus is painful and disfiguring, only a small proportion of the workmen are attacked, and the mortality is low, 15 to 20 per cent. Since the abolition of the white phosphorus match, but little white phosphorus is used in American industries; during the Great War it was used in an incendiary projectile. Ferrosilicon may evolve phosphine (hydrogen phosphide) as well as arsine.

J. S. H.

American Philosophical Society, Papers Presented at the Meeting of April 24, 1920. L. A. BAUER.—*The Relation of the Recent Solar Eclipse to the Einstein Theory.*—The eclipse of 1919 was peculiarly favorable for testing this theory because several bright stars were near the sun at the time. By the theory of gravitation advanced by the Swiss scientist these stars should have appeared to be displaced 1.74 seconds along lines joining them to the sun. In fact, early reductions of the results showed that in general they were

not displaced along this line, but were displaced in other directions about 2 secs. When Doctor Bauer took into account second order terms in correcting for atmospheric refraction, not only was the angle of displacement calculated from the observations reduced to 1.77 secs. but in addition the departure from the radial directions disappeared altogether.

D. C. MILLER.—*Velocity of Air Waves from Explosions.*—When a steamer travels in quiet water a water wave travels in advance of it. Similarly a rapidly moving projectile is preceded by an air wave. As this keeps ahead of the shell and as the latter travels faster than sound, it follows that the wave travels faster than sound. It spreads out to the sides. Professor Miller finds by experiment that, even when the nose-wave has a velocity of 2720 ft. per sec., the lateral parts of the wave, distant only two or three lengths of the projectile from the foremost part, travel with normal velocity.

The wave which leaves the muzzle of a 14-inch gun at first moves faster than ordinary sound waves, but at a distance of about 800 ft. its velocity comes down to normal.

Arthur G. Webster in discussing this paper showed a slide in which variations of air pressure caused by the passing of a bullet were recorded. The frequency was about 3000 per sec. This accounts for the whistle of the bullet.

J. B. WHITEHEAD.—*Uses of the Electrical Corona.*—When a sudden strain is thrown upon a transmission line by lightning or otherwise it has been noticed that lines operating with very high voltage—and in consequence with a corona—suffer less damage than those at lower voltages. It is proposed to have the voltage of the line not at, but a little below the point necessary for the development of the corona. Then when a sudden rise of electrical pressure occurs, the corona will form and will act as a sort of safety-valve by dissipating energy.

A second use is for the measurement of crest values of high A. C. voltages. With round wires the corona appears at definite voltages, depending on the diameter of the wire and on the pressure and temperature of the air. An instrument has been devised by which applied potentials up to 400,000 volts can be measured from the known connection of the corona with the three variables. The corona is detected by its causing the air to become a conductor, thus enabling a current to flow through a galvanometer. In a confined space the corona is accompanied by a loud noise.

H. C. HAYES.—*The M-V Hydrophone.*—This instrument, which was designed for the detection of submarines, can locate the direction along which sounds reach it through water with an accuracy of two degrees. When the *Von Steuben* with a hydrophone installed on board left New York, the craft in the harbor were located and the lightships, which were giving sound signals, were picked up before they could be seen. Sounds emanating from the *Nantucket* lightship were heard for two hours, the shortest distance being 32

and the longest 40 miles. Later in the voyage vessels could not be detected. In fact, the sound of the *Von Steuben's* own propellers was inaudible. It developed that the hydrophone is useful only in shallow water. Only such sounds as are reflected from the bottom are heard.

Depths of water can be measured by the same instrument up to distances equal to three times the length of the vessel on which it is mounted. The accuracy of the measurement increases as the depth grows less. On a voyage during which the continental shelf was crossed soundings were made by using the hydrophone and then compared with the results obtained by a sounding machine, by hand and from a chart. When any two of the last three agreed, then the hydrophone results agreed also.

Since the direction of fixed objects, such as lightships, can be determined and in addition the depth of water can be measured, this instrument promises much usefulness in navigation. To test this a run was made in a fog with a submarine from Salem, Mass., to Portland, Me., and back to the southern coast of New England. The voyage was accomplished in safety and the location of the vessel was determined with surprising accuracy.

G. F. S.

Physiological Action of Nitrobenzene Vapor on Animals.—WALLACE LARKIN CHANDLER reports the results of a research on this subject in *Memoir 20 of the Cornell University Agricultural Experiment Station.* Nitrobenzene (oil of mirbane) exerts a toxic action when ingested, inhaled, applied to the skin, or injected beneath the skin. The lethal dose, *i.e.,* the dose required to produce death, is extremely variable. The digestive functions may be disturbed, and asphyxia may be produced by direct action on the blood. The red blood cells are altered; and the hæmoglobin is changed to methemoglobin. However, most of the symptoms of poisoning by nitrobenzene are due to its action on the brain, for it produces degeneration of the Purkinje cells of the cerebellum. The size of the lethal dose and the length of the latent period, which occurs between the actual poisoning and the onset of the symptoms, depends on the amount of fat in the blood and the body of the poisoned animal; the nitrobenzene enters the blood, and then is absorbed by the body fat; as its concentration in the blood decreases, it is given up by the body fat to the blood fat, carried by the latter to the brain, and deposited in the brain cells. The following conclusions are reached: Nitrobenzene cannot be safely used for the fumigation of animals to destroy their external parasites, and should not be used as an ingredient of flavoring extracts, or as a perfume in soaps and toilet articles, or as a solvent in shoe polish and floor wax. It should be given serious consideration as an industrial poison in the dyestuff and related industries.

J. S. H.

Distribution of the Chemical Elements.—Geochemists have calculated the percentage by weight of the different elements in the known crust of the earth, including the rocks, water, and atmosphere. INGO W. D. HACKH (*Science Progress,* 1920, xiv, 602–607) has used these figures as the basis of his calculations. If the per cent. of each element, which is present, be divided by its atomic weight, the quotient shows the relative proportion of its atoms in the crust. Of the 25 elements, whose atoms are most abundant, those of bromine are least abundant; and the relative proportion of bromine atoms was therefore taken as unity; the other elements then fell into the following order of magnitude with respect to the occurrence of their atoms:

O....	249,850	Mg ...	6,835	Ti.....	714	N	171	V.....	23
H....	75,312	Ca....	6,422	Cl.....	451	Mn.....	116	Li.....	22
Si....	72,860	Fe....	5,982	F.....	421	Ba.....	46	Sr.....	16
Al....	21,528	K.....	4,660	P.....	283	Cr.....	46	Zr.....	13
Na...	8,200	C.....	1,199	S.....	274	Ni.....	26	Br.....	1

Hydrogen thus follows directly after oxygen with respect to the relative occurrence of its atoms.

J. S. H.

The Dissipation of Heat by Various Surfaces in Still Air. T. S. TAYLOR. (*Phys. Rev.,* March, 1920.)—Three vessels of sheet tin, 10 cm. in diameter and 50 cm. long, were made. One was left bare, one was covered closely with sheet asbestos 0.33 mm. thick and the third was covered loosely with the same material. All three were filled with hot water and allowed to cool under similar conditions. The result was obtained that the bare vessel lost only 70 per cent. as much heat per minute as the loosely covered one and 63 per cent. as much as the tightly covered vessel. The effect of dusting the surface with coal ashes was to slightly increase the radiation from the bare surface and to diminish to a somewhat greater extent the loss from the tightly covered vessel.

G. F. S.

Variation of Transparency to Total Radiation with Temperature of Source. S. L. BROWN. (*Phys. Rev.,* March, 1920, p. 217.)—Glass, rock salt, mica, celluloid and paraffin were examined. In all the transparency for total radiation increased markedly as the temperature of the radiating body rose from 200° to 1200° C. For glass the amount transmitted at the lower temperature was 5.8 per cent. and at the higher 61 per cent. For rock salt the corresponding numbers are 35 and 50.5. Glass alone shows a departure from the general rule by having a minimum transmission at 300°. Whether heated or cooled from this temperature its transmission increases.

G. F. S.

The Nuclei of Atoms and the New Periodic System. W. D. HARKINS. (*Physical Review,* February, 1920.)—Formulæ are given for the composition of the atoms and of the nuclei of the first 27 elements and of the radio-active elements. An atom of sulphur is given as consisting of 8 helium atoms, while its nucleus is made up of the same number of helium nuclei. Nothing but helium and hydrogen atoms appear in the formulæ for atoms, but in the nuclei there are also beta particles in addition to the nuclei of the two elements just mentioned. In general the nuclei of the even numbered light elements consist altogether of helium nuclei, while the odd numbered elements have in their nuclei an additional group, consisting of 3 hydrogen nuclei and 2 beta particles. The elements from 28 to 80 in atomic number do not fall in with this scheme, and it is suggested that they may consist of mixtures of isotopes.

"In a note appended at the time of correcting the proof for this paper, the writer states that his latest atomic weight results seem to indicate that he has obtained an experimental separation of chlorine into isotopes."

G. F. S.

Nature of the Process of Ionization of Gases by Alpha Rays. R. A. MILLIKAN, V. H. GOTTSCHALK and M. J. KELLY. (*Phys. Rev.,* March, 1920, p. 157.)—Alpha rays from radium bombarded the molecules of air, carbon dioxide, carbon tetrachloride, methyl iodide and mercury dimethyl. Thus atoms of H, C, O, N, Cl, I and Hg, with a range of atomic weight from 1 to 200, were traversed by the rapidly moving rays. The residues of the ionized atoms were caught on oil drops and their electrical charges measured. This was done in 2900 cases of which only five corresponded to double charges and none at all to triple or larger charges. "The results prove that, at least, 99 times out of 100, ionization by an Alpha ray, in the case of each of the gases and vapors studied, consists in the detachment of a single elctron from a molecule."

G. F. S.

Digestibility of Chicken Skin.—EDWARD F. KOHMAN and H. A. SHONLE (*Journal of Biological Chemistry,* 1920, xli, 469–472) have made metabolism experiments on human subjects concerning the utilization of the proteins or nitrogenous constituents and the fat of the skin of the common fowl. The results showed that, when 65.1 to 67.5 per cent. of the nitrogen of the diet was supplied by chicken skin, the utilization of the nitrogen was as good as when the same proportion of the nitrogen was supplied by meat, eggs, and milk. The utilization of the ingested fat likewise was practically the same on the chicken-skin diet, and on the diet of meat, eggs, and milk.

J. S. H.

The Production of Power from Blast Furnace Gas. S. H. FOWLES. (*Electrician*, March 26, 1920.)—Sir Charles A. Parsons, Franklin medallist, "has estimated that the total available water-power in the British Isles is only 1½ million horse-power, and that England possesses only one per cent. of the water-power and 2½ per cent. of the total coal in the world." The blast furnaces of Great Britain annually waste a million horse-power. The following table compares the old method with the Halberg-Beth type of plant:

	Old Method	New Method
Gas made per furnace per hour	1,000,000 cu. ft.	1,000,000 cu. ft.
Gas used per furnace per hour	1,000,000 cu. ft.	550,000 cu. ft.
Coke per ton of pig iron made	23 cwt.	21 cwt.
Units of electricity generated per furnace per annum	None	6,870,000
Potash saved per annum	None	£6,000
Flue cleaning costs per annum	£1,000	None
Coal used per furnace per hour	0.5 ton	0.2 ton
Horse-power developed per furnace per hour	600	800

G. F. S.

Heat production during luminescence has been studied by E. NEWTON HARVEY (*Journal of General Physiology*, 1919, ii, 137–143). *Cypridina hilgendorfi*, a small crustacean, contains a compound luciferin and an enzyme luciferase, which oxidizes the luciferin to oxyluciferin in the presence of water and oxygen; this reaction is accompanied by the production of light, and is the cause of the bioluminescence of the living animal. Both the luciferin and the luciferase are soluble in water; and a solution may be prepared containing only one or the other of the two substances. A solution of luciferin was mixed with one of luciferase in a suitable apparatus, and the change in temperature noted. The results indicated that 1 gram of luciferin liberates less than 0.1 small calorie during the luminescence which accompanies its oxidation.

J. S. H.

Duration of Light Emission from a Radiating Hydrogen Atom. A. J. DEMPSTER. (*Physical Review*, February, 1920.)—Canal rays were shot through a hole from a discharge tube into a second tube with a much higher vacuum. After moving about 4 cm. beyond the hole the luminosity of the particles died out. From the Doppler effect exhibited by the rays the speed of the particles was found to be 90,000,000 cm. per second. Hence the time required for the light to die away beyond the hole was about five hundred-millionths of a second. The light was chiefly that of the beta line of hydrogen.

G. F. S.

Use of Cirrus Clouds in Forecasting the Weather. G. REBOUL and L. DUNOYER. (*Comptes Rendus,* March 22, 1920.)—The appearance of cirrus clouds has for a long time been known to be connected with the shifting of barometric pressures. The authors have subjected certain phases of this relation to the test of comparison over considerable lengths of time. In 93 per cent. of the cases it was true that the appearance of this type of cloud indicated a barometric depression in the neighborhood. In 82 per cent. of the cases the direction in which these clouds moved was toward the depression. The agreement in France was, however, much better for a motion from the west than in the opposite direction. In about 63 per cent. of the cases the cirrus clouds moved in the same general direction as the depression. Seventy per cent. of the times a great velocity in these clouds means a great velocity in the motion of the depression. The development of cirrus clouds in quantity means either that the depression is close at hand or that it is quite considerable in amount.

G. F. S.

Acid Solutions.—The relationship between the total acidity, the concentration of the hydrogen, and the taste of acid solutions has been investigated by R. B. HARVEY (*Journal of the American Chemical Society,* 1920, xlii, 712–714). Total acidity is the *total* amount of *free acid* present in the solution, and includes both that in the molecular state and that dissociated into its ions. Concentration of the hydrogen ion represents the hydrogen ions, and therefore measures the *dissociated free acid* present in the solution. Harvey's results indicate that the sour or acid taste of an acid solution depends on both the total acidity and the hydrogen ion concentration. It is therefore desirable that both these values be determined in the case of acid foods. The addition of sugar alters the taste, but does not change either the total acidity or the hydrogen ion concentration.

J. S. H.

The Constitution of Atmospheric Neon. F. W. ASTON. (*Phil. Mag.,* April, 1920.)—By the use of the Positive Ray Spectrograph it has been proved that neon contains two isotopes of atomic weights, 20.00 and 22.00 respectively. Their ratio by volume is 9 : 1. There is some indication of the existence of a third isotope.

G. F. S.

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